

BIOLOGICAL CONTROL OF THE CITRUS BLACKFLY (ALEUROCANTHUS WOGLUMI
ASHBY) BY PROSPALTELLA OPULENTA SILV. IN CENTRAL-WESTERN VENEZUELA
WITH A REVIEW OF THE PEST'S INVASION OF THE WESTERN HEMISPHERE
AND SUPPRESSION BY INTRODUCED PARASITES

BY

HUGO A. CHAVEZ TORRES

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF THE
UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1930

Dedicated

to

My Parents Alejandro and Basilisa

My Wife Maria Ines

My Son Luis Alejandro

My Daughters Maria Sofia and Monica Maria

The Universidad Centro Occidental Lisandro Alvarado

My Students

ACKNOWLEDGEMENTS

I am deeply indebted to the Chairman of my graduate committee, Dr. Reece I. Sailer, for his suggestions, guidance, assistance and advice throughout this study.

Special thanks are extended to Dr. Donald E. Short, Dr. James L. Nation, Dr. Jerry L. Stimac, and Dr. Francis W. Zettler who served as members of the author's supervisory committee for critical review of the first draft of the dissertation.

I am personally grateful to Mr. A. Martinez (Hacienda Santa Lucia), Juconasa Industries (Apoliro Experimental Orchard), and Mr. G. Gascon (Gloria de Lara) whose valuable collaboration helped greatly to make possible this study, and to the team of Entomology of the Escuela de Agronomia (UCOLA) for its valuable collaboration, encouragement and support.

I wish to express my gratitude to Ing. Agr. Hector Ochoa Z., Rector of the Universidad Centro Occidental Lisandro Alvarado, to Ings. Agrs. Orlando Molina and Omar Gimenez, Directors of the Escuela de Agronomia, to Consejo Asesor de Investigaciones y Servicios, whose support made this study possible, to Ings. Agrs. Francis Geraud, Nancy de Martinez and Jorge Teran for their cooperation in obtaining stock of Prospaltella opulenta for purposes of this study and to Ing. Agr. Liz de Rodriguez for her assistance and guidance in the statistical analysis.

I wish also to remember Dr. Milledge Murphy, former member of the supervisory committee and professor of the University of Florida, now deceased.

I extend my sincerest appreciation to my wife, Maria Ines, for her support and enthusiasm during the time of the study.

Finally, I am deeply indebted to Dr. Jose M. Osorio, professor of the Escuela de Agronomia (UCOLA) who introduced me to entomology and through his teaching, general guidance and assistance encouraged me to seek a career in this field.

TABLE OF CONTENTS

CHAPTER	PAGE
ACKNOWLEDGEMENTS.	iii
LIST OF TABLES.	vi
LIST OF FIGURES	viii
ABSTRACT.	xi
I INTRODUCTION.	1
II A REVIEW OF LITERATURE.	3
Taxonomic Position, Synonymy and Common Names. . .	3
Origin and Distribution.	4
Biology.	10
Life History	13
Host Plants.	16
Damage or Injury	18
Biological Control in the Western Hemisphere . . .	18
Countries of the Western Hemisphere Where Natural Enemies Have Been Introduced for Control of Citrus Blackfly.	25
III BIOLOGICAL CONTROL OF CITRUS BLACKFLY IN THE CENTRAL- WESTERN REGION OF VENEZUELA	36
Materials and Methods.	37
Host Plants	37
Locations	37
Sampling Procedure.	38
Count	38
Mortality Factors	39
Statistical Analysis.	39
Parasite.	39
Results.	40
Hacienda Santa Lucia.	40
Apoliro Experimental Orchard.	61
Gloria de Lara Citrus Orchard	79
Statistical Analysis.	97
Discussion	105
LITERATURE CITED.	109
BIOGRAPHICAL SKETCH	118

LIST OF TABLES

TABLE		PAGE
1	PERCENT HEALTHY AND DEAD NYMPHAS OF <u>A. WOGLUMI</u> ON 60 SAMPLED LEAVES PER DATE LOCALITY: <u>YARITAGUA</u> (HACIENDA "SANTA LUCIA")	48
2	SUMMARY OF MONTHLY DATA RELATING TO TEMPERATURE, RELATIVE HUMIDITY, RAINFALL AND EVAPORATION FOR "APOLIRO" AND "SANTA LUCIA" ORCHARDS.	51
3	EGGS, PUPAE AND ADULTS OF <u>A. WOGLUMI</u> ON 60 SAMPLED LEAVES PER DATE LOCALITY: <u>YARITAGUA</u> (HACIENDA "SANTA LUCIA").	55
4	PERCENT PARASITISM OF DISSECTED LIVE FORMS OF <u>A. WOGLUMI</u> ON 60 LEAVES PER SAMPLE LOCALITY: <u>YARITAGUA</u> (HACIENDA "SANTA LUCIA")	58
5	PERCENT HEALTHY AND DEAD NYMPHS OF <u>A. WOGLUMI</u> ON 60 SAMPLED LEAVES PER DATE LOCALITY: <u>CABUDARE</u> ("APOLIRO" EXPERIMENTAL ORCHARD).	70
6	EGGS, PUPAE AND ADULTS OF <u>A. WOGLUMI</u> ON 60 SAMPLED LEAVES PER DATE LOCALITY: <u>CABUDARE</u> ("APOLIRO" EXPERIMENTAL ORCHARD)	72
7	PERCENT PARASITISM OF DISSECTED LIVE FORMS OF <u>A. WOGLUMI</u> ON 60 LEAVES PER SAMPLE LOCALITY: <u>CABUDARE</u> ("APOLIRO" EXPERIMENTAL ORCHARD)	77
8	EGGS, PUPAE AND ADULTS OF <u>A. WOGLUMI</u> ON 60 SAMPLED LEAVES PER DATE LOCALITY: <u>SARARE</u> ("GLORIA DE LARA" CITRUS ORCHARD)	84
9	SUMMARY OF MONTHLY DATA RELATING TO RAINFALL FOR "GLORIA DE LARA" CITRUS ORCHARD	86
10	PERCENT HEALTHY AND DEAD NYMPHS OF <u>A. WOGLUMI</u> ON 60 SAMPLED LEAVES PER DATE LOCALITY: <u>SARARE</u> ("GLORIA DE LARA" CITRUS ORCHARD)	90
11	PERCENT PARASITISM OF DISSECTED LIVE FORMS OF <u>A.</u> <u>WOGLUMI</u> ON 60 LEAVES PER SAMPLE LOCALITY: <u>SARARE</u> ("GLORIA DE LARA" CITRUS ORCHARD).	95

TABLE		PAGE
12	CORRELATION COEFFICIENTS FOR SQUARE CENTIMETER AND TOTAL LEAF COUNTS FOR EACH VARIABLE STUDIED AT HACIENDA SANTA LUCIA.	98
13	CORRELATION COEFFICIENTS FOR SQUARE CENTIMETER AND TOTAL LEAF COUNTS FOR EACH VARIABLE STUDIED AT APOLIRO EXPERIMENTAL ORCHARD.	99
14	CORRELATION COEFFICIENTS FOR SQUARE CENTIMETER AND TOTAL LEAF COUNTS FOR EACH VARIABLE STUDIED AT GLORIA DE LARA CITRUS ORCHARD	100
15	PREDICTION EQUATION INCLUDING THE LINEAR AND QUADRATIC EFFECT OF THE COUNT PER SQUARE CENTIMETER AND R^2 VALUES FOR HACIENDA SANTA LUCIA	101
16	PREDICTION EQUATION INCLUDING THE LINEAR AND QUADRATIC EFFECT OF THE COUNT PER SQUARE CENTIMETER AND R^2 VALUES FOR APOLIRO EXPERIMENTAL ORCHARD	102
17	REGRESSION COEFFICIENTS, STANDARD ERROR AND PROBABILITY > t FOR EGGS, NYMPHAL (FIRST, SECOND, AND THIRD INSTAR) AND PUPAE FOR HACIENDA SANTA LUCIA.	103
18	REGRESSION COEFFICIENTS, STANDARD ERROR AND PROBABILITY > t FOR EGGS, NYMPHAL (FIRST, SECOND, AND THIRD INSTAR) AND PUPAE FOR APOLIRO EXPERIMENTAL ORCHARD.	104

LIST OF FIGURES

FIGURE		PAGE
1	Map showing the countries and dates where the citrus blackfly has been reported in the Western Hemisphere.	7
2	Places where <u>P. opulenta</u> has been released in Venezuela and where <u>A. woglumi</u> was first observed	34
3	Hacienda Santa Lucia, Yaritagua.	41
4	Egg and adult populations of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "California" at Hacienda Santa Lucia, Yaritagua.	42
5	First, second, and third nymphal instars of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "California" at Hacienda Santa Lucia, Yaritagua.	43
6	Total, healthy, and dead first nymphal instar populations of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "California" at Hacienda Santa Lucia, Yaritagua.	45
7	Total, healthy, and dead second nymphal instar populations of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "California" at Hacienda Santa Lucia, Yaritagua.	46
8	Total, healthy, and dead third nymphal instar populations of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "California" at Hacienda Santa Lucia, Yaritagua.	47
9	Average monthly temperature, relative humidity, rainfall, and evaporation (shadow) for Santa Lucia and Apoliro Citrus Orchards	50
10	Total, healthy, dead, and parasitized pupa populations of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "California" at Hacienda Santa Lucia, Yaritagua . . .	54
11	Percent healthy and parasitized (with hole) pupae and percent dissected parasitism of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "California" at Hacienda Santa Lucia, Yaritagua	57

FIGURE		PAGE
12	Apoliro Experimental Orchard, Cabudare.	62
13	Egg and adult populations of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "Pineapple" at Apoliro Experimental Orchard, Cabudare	63
14	First, second, and third nymphal instars of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "Pineapple" at Apoliro Experimental Orchard, Cabudare	64
15	Total, healthy, and dead first nymphal instar populations of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "Pineapple" at Apoliro Experimental Orchard, Cabudare	66
16	Total, healthy, and dead second nymphal instar populations of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "Pineapple" at Apoliro Experimental Orchard, Cabudare	68
17	Total, healthy, and dead third nymphal instar populations of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "Pineapple" at Apoliro Experimental Orchard, Cabudare	69
18	Total, healthy, dead, and parasitized pupa populations of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "Pineapple" at Apoliro Experimental Orchard, Cabudare	75
19	Percent healthy and parasitized (with hole) pupae and percent dissected parasitism of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "Pineapple" at Apoliro Experimental Orchard, Cabudare	76
20	Glorida de Lara, Sarare	80
21	Egg and adult populations of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "Valencia" at Gloria de Lara, Sarare.	82
22	First, second, and third nymphal instars of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "Valencia" at Gloria de Lara, Sarare.	83
23	Total, healthy, and dead first nymphal instar populations of <u>A. woglumi</u> observed on leaves of <u>C. sinensis</u> var. "Valencia" at Gloria de Lara, Sarare	87

24	Total, healthy, and dead second nymphal instar populations of <i>A. woglumi</i> observed on leaves of <i>C. sinensis</i> var. "Valencia" at Gloria de Lara, Sarare.	88
25	Total, healthy, and dead third nymphal instar populations of <i>A. woglumi</i> observed on leaves of <i>C. sinensis</i> var. "Valencia" at Gloria de Lara, Sarare.	89
26	Total, healthy, dead, and parasitized pupa populations of <i>A. woglumi</i> observed on leaves of <i>C. sinensis</i> var. "Valencia" at Gloria de Lara, Sarare.	92
27	Percent healthy and parasitized (with hole) pupae and percent dissected parasitism of <i>A. woglumi</i> observed on leaves of <i>C. sinensis</i> var. "Valencia" at Gloria de Lara, Sarare.	94

Abstract of Dissertation Presented to the Graduate Council
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

BIOLOGICAL CONTROL OF THE CITRUS BLACKFLY (ALEUROCANTHUS WOGLUMI
ASHBY) BY PROSPALTELLA OPULENTA SILV. IN CENTRAL-WESTERN VENEZUELA
WITH A REVIEW OF THE PEST'S INVASION OF THE WESTERN HEMISPHERE
AND SUPPRESSION BY INTRODUCED PARASITES

By

Hugo A. Chavez Torres

June 1980

Chairman: R. I. Sailer

Major Department: Entomology and Nematology

The citrus blackfly, Aleurocanthus woglumi Ashby, is assumed to be a native of India, India and Pakistan, South Asia, Southern China, and Asia. Specimens were first received by USDA, Entomology, in 1910 from Maxwell-Lefroy in India. The first report of A. woglumi in the Western Hemisphere was made by Ashby in Jamaica in 1915. From here the citrus blackfly invaded other countries and now is widely distributed in the Western Hemisphere.

The introduction of the natural enemies from Asia to the Western Hemisphere can be divided into 2 stages. The first stage began in 1930, with shipment of Eretmocerus serius from Malaya to Cuba, where it was successfully established and controlled the citrus blackfly. This parasite was later introduced into other countries of the Hemisphere. The second stage began in 1949, with the shipment of parasitized material from India and Pakistan to Mexico. Of the

species of parasites received in Mexico, Amitus hesperidum, Prospaltella opulenta, and P. clypealis proved to be the most effective in the control of the pest and were later introduced into other countries of the Hemisphere.

After being found and eradicated by means of chemical applications from Florida (1937) and Texas (1955), the citrus blackfly reinvaded Texas in 1967 and Florida in 1976. It proved unfeasible, if not impossible, to eradicate these infestations, and both are now effectively controlled by parasites. Parasites have provided highly satisfactory control in all infested countries where they have been introduced. When earlier control seemed to break down (Jamaica), the situation was corrected by introduction of a second species of parasite. In Mexico, where adverse climatic or cultural factors cause sporadic local outbreaks, control is reestablished by reintroducing parasites from localities where they are abundant.

In Venezuela, A. woglumi was first found in 1967 at San Antonio del Tachira and was first observed in Barquisimeto in 1968. By 1974, the citrus blackfly was widespread through all the country. The first shipment of Prospaltella opulenta from Mexico was received in 1975. Additional shipments were received in June 1976, and positive evidence of establishment was obtained between June and September. Beginning November 11, 1976, egg, nymphal, pupal and adult stages of the citrus blackfly were sampled at 3 citrus grove locations. The sample procedure included standardized leaf counts for the immature stages. Adult populations were determined by visual counts. Leaf samples included square centimeter counts and were compared with whole leaf counts in an effort to establish reliability of the less

laborious square inch method showing high correlation coefficients. Mortality factors were identified in the field as well as in the leaf samples; however, the combined effect of these observed and suspected mortality factors did not prevent the increase of citrus blackfly populations when more favorable conditions returned. After the release of P. opulenta the number of dead citrus blackflies increased as an effect of parasite host feeding as well as by stinging activity of the female parasite that fails to result in parasite development. Cales sp., a native parasite, probably played an important role as a host of the male P. opulenta which develops as secondary parasite and thus hastened the establishment and colonization of P. opulenta. As the introduced parasite increased to a level having a measurable effect on the host population, Cales sp. was displaced as a parasite of A. woglumi. The increase of the P. opulenta population was followed and its impact on the host population established. Complete biological control was achieved in 18 months after P. opulenta was released in the Central-Western region of Venezuela.

CHAPTER I INTRODUCTION

Citrus is second only to apples in world trade. They belong to six genera, namely, Fortunella, Eremocitrus, Clymenia, Poncirus, Microcitrus and Citrus, but from an economic point of view, only Fortunella, Poncirus and Citrus are important (Chapot, 1975). Fortunella (kumquats), Poncirus (trifoliate orange) and Citrus (shaddock, mandarin, sour orange, sweet orange, lime, citron, lemon, and other types of fruits including natural hybrids) are native to a very large asiatic area. The grapefruit is an exception. It (C. paradisi Macfadyen) appeared, probably as a hybrid, in Barbados (West Indies). The 2 main species of Fortunella are native to Southern China and the genus Poncirus to Central and Northern China. The mandarin (C. reticulata Blanco) is believed to be native to Indochina and Southern China, the lime (C. aurantifolia Swingle) to the East Indian Archipelago, the shaddock (C. grandis Osbeck) to the East Indian Archipelago, the citron (C. medica L.) to Southern China and India. The origin of lemon (C. limon Burmann) is totally unknown, the sweet orange (C. sinensis Osbeck) probably originated in Indochina and Southern China, and the sour orange (C. aurantium L.) is possible indigenous to India (Chapot, 1975).

Citrus crops are grown in a belt between 40° north and 40° south latitude, high elevations excepted. In the equatorial part of this belt (15° north and south) constant high temperature induces several crops a year, poor coloration of fruit and fast development of pests.

Subtropical, temperate and mediterranean types of climates characterized by low humidity, a cold winter and considerable daily change of temperature induces good color, tastier flesh and uniform ripening of the crop. Beyond the 40° latitude, the problem of recurrent freezes can to a certain extent be alleviated by choice of particular scion and rootstock varieties.

Semitropical Florida, Brazil and Japan fall between these 2 zones and have intermediate characteristics (Chapot, 1975).

Citrus fruits are marketed not only as table fruit, but as processed products in the form of beverage flavor bases, frozen concentrates, chilled pasteurized juice, canned single-strength juice, lime and lemonades, canned segment, salads, cosmetics, perfumes, dye-stuffs and many others (Kesterson and Braddock, 1975).

The production of citrus fruit (sweet orange) in Venezuela for 1978 was 262.690 metric tons harvested from 27.806 Ha (Fomento Agropecuario, 1980).

The most important groups of citrus pests worldwide are fruit flies, scale insects, mites and whiteflies (including citrus blackfly).

CHAPTER II A REVIEW OF LITERATURE

Taxonomic Position, Synonymy and Common Names

Aleurocanthus woglumi Ashby is a member of the homopterous family Aleyrodidae. Because of the appearance of the adult stage, it is commonly referred to as the citrus blackfly. It was first described by S. F. Ashby (Ashby, 1915). There has been no recent taxonomic treatment of the family, and the most definitive work remains that of Quaintance and Baker (1913-14). They noted that "unfortunately" the pupal stage was the life form most readily used in identification and classification of species. Pupae continue to be the most readily identified. The genus Aleurocanthus is widely distributed throughout the tropical to lower temperate regions and includes the species listed below which are currently treated as valid members of the genus and are potentially serious pests of citrus (Quaintance and Baker, 1916).

A. citricolus (Newstead)

A. citriperdus Quaintance and Baker

A. woglumi Ashby

A. spiniferus (Quaintance)

Other members of this family commonly encountered often as serious pests on citrus are (Quaintance and Baker, 1916):

Aleurolobus marlatti (Quaintance)

Aleurothrixus floccosus (Maskell)

Aleurothrixus howardi (Quaintance)

Aleurothrixus porteri Quaintance and Baker

Bemisia giffardi (Kotinsky)

Dialeurodes citri (Ashmead)

Dialeurodes citrifolii (Morgan)

Paraleyrodes perseae (Quaintance)

Trialeurodes floridensis (Quaintance)

Trialeurodes vitrinellus (Cockerell)

Tetraleurodes mori (Quaintance)

Tetraleurodes mori var. arizonensis (Cockerell)

Synonymous and common names for A. woglumi Ashby are the following:

Synonymous:

Aleurocanthus woglumi (Quaintance) (Ashby, 1915)

A. punjabensis Corbett (1935a)

A. woglumi var. formosana Takahashi (1935)

Common names:

Mosca prieta, citrus blackfly, blackfly, black scale (in Jamaica), blue fly, citrus bluefly (in Bahamas). The most used common names are Mosca prieta and citrus blackfly.

Origin and Distribution

The citrus blackfly has been treated as a native of India (Ashby, 1915; Dietz and Zetek, 1920; Wolcott, 1933; Weems, 1962), India and Pakistan (Osorio et al., 1972), South Asia (Jimenez, 1963; Smith et al., 1964; Enkerlin, 1976), Southern China (Clausen and Berry, 1932), Asia

(Russell, 1962; Howard and Neel, 1977; Dowell and Fitzpatrick, 1978; Dowell et al., 1979; Dowell, 1979a).

The citrus blackfly was first received by the U. S. Dept. of Agriculture, Bureau of Entomology, in 1910 from Maxwell-Lefroy in India and subsequently from George Compere in the Philippine Islands and R. S. Woglum in India and Ceylon. The citrus blackfly is now widely distributed in most of the citrus growing areas:

Africa

Kenya (Wheatley, 1964; Hill, 1975)

South Africa: Durban (Bosman, 1959; Russell, 1962; Bedford and Thomas, 1965).

Seychelle Islands (Russell, 1962; Browne, 1968)

Asia

Aden (Knorr et al., 1961; Russell, 1962; Gentry, 1965)

Bangladesh (Alam et al., 1965)

Burma (Clausen and Berry, 1932)

Ceylon (Srilanka) (Quaintance and Baker, 1916; Russell, 1962)

China

Canton: Wangtung (Wu, 1935)

Southern China (Clausen and Berry, 1932; Weems, 1962)

India

Surat, Ahmadabad: Gujarat (Smith et al., 1964)

Andra Pradesh (State), Assam (State), Bihar (State), Delhi, Madhya Pradesh (State) (Anonymous, 1959).

Calcutta: Bengal (Smith et al., 1964)

Sikkim (Quaintance and Baker, 1916; Dietz and Zetek, 1920)

- Nagpur: Maharashtra (Quaintance and Baker, 1916; Dietz and Zetek, 1920)
- Bombay: Maharashtra (Husain and Kahn, 1945)
- Poona: Maharashtra (Smith et al., 1964)
- Mysore: Mysore (Smith et al., 1964)
- Cuttack: Orissa (Smith et al., 1964)
- Madras: Tamil Nadu (Smith et al., 1964)
- Kalimpong: West Bengal (Quaintance and Baker, 1916)
- Dehra Dun, Saharapur: Uttar Pradesh (Smith et al., 1964)
- Indochina (Clausen and Berry, 1932; Weems, 1962)
- Indonesia (Dutch East Indies, Weems, 1962)
- Java, Sumatra (Clausen and Berry, 1932; Russell, 1962)
- Iran (Kiriukhin, 1947; Gentry, 1965)
- Korea (Muller, 1956)
- Malaya: Kuala Lumpur, Malacca, Serdang, Selangor (Clausen and Berry, 1932; Corbett, 1935b; Clausen, 1936; Russell, 1962; Weems, 1962)
- Philippines: Manila (Quaintance and Baker, 1916; Pratt, 1958; Russell, 1962; Weems, 1962)
- Pakistan: Sind (Abbas et al., 1955; Russell, 1962)
- Oman (Watts and Alam, 1973; Simmonds, 1975)
- Singapore (Silvestri, 1926; Russell, 1962)
- Thailand (Siam): Bangkok (Clausen and Berry, 1932; Takahashi, 1942; Weems, 1962)
- Turkey (Anonymous, 1968)
- Central America and West Indies (Fig. 1)
- Bahamas (Quaintance and Baker, 1916; Newell, 1918; Wolcott, 1933; Richardson, 1948; Russell, 1962; Weems, 1962)

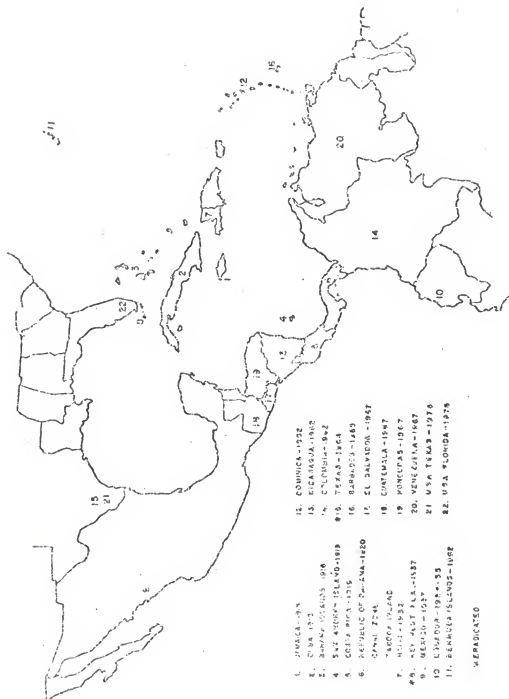


Figure 1. Map showing the countries and dates where the citrus blackfly has been reported in the Western Hemisphere.

- Bermuda (Russell, 1962)
- Barbados (Bennett and van Whervin, 1965; Pschorn-Walcher and Bennett, 1967)
- Costa Rica (Zetek, 1919; Wolcott, 1933; Russell, 1962; Osorio et al., 1972)
- Cuba (Quaintance and Baker, 1916; Anonimo, 1917; Hutson, 1917; Bruner, 1931; Berry and McGough, 1932; Wolcott, 1933; Bruner et al., 1945; Osorio, 1946; Bruner, 1954; Osorio et al., 1972)
- Canal Zone (Dietz and Zetek, 1920; Wolcott, 1933)
- Dominica (Russell, 1962)
- El Salvador (McGuire and Crandall, 1967; Quezada, 1974)
- Guatemala (McGuire and Crandall, 1967)
- Haiti (Dozier, 1932, 1933; Wolcott, 1933; Russell, 1962, Weems, 1962)
- Honduras (McGuire and Crandall, 1967)
- Jamaica (Ashby, 1915; Quaintance and Baker, 1916; Wolcott, 1933)
- Nicaragua (Russell, 1962; McGuire and Crandall, 1967)
- Republic of Panama (Dietz and Zetek, 1920; Wolcott, 1933; Russell, 1962; Osorio et al., 1972)
- Taboga Island (Dietz and Zetek, 1920)
- San Andres Island (Republic of Colombia) (Zetek, 1919)
- North America (Fig. 1)
- Mexico
- El Dorado: Sinaloa (Baker and Dampf, 1937)
- Aguas Calientes, Baja California, Colima, Campeche, Chihuahua, Durango, Guanajato, Guerrero, Hidalgo, Jalisco,

Morelos, Michoacan, Nayarit, Nuevo Leon, Oaxuco, Puebla,
 Sonora, San Luis Potosi, Tamaulipas, Zacatecäs (Jimenez,
 1963; Mateos, 1963; Smith et al., 1964; Carrillo et
 al., 1966; Jimenez, 1968).

Coahuila, Mexico D.F., Queretaro, Simalca, Uruapan,
 Vera Cruz (Russell, 1962)

U.S.A.

Florida

Key West (Brown, 1937; Brown, 1939; Newell and Brown,
 1939) (Eradicated)

Broward County (Anonymous, 1976a; Cherry et al., 1978)

Palm Beach County (Anonymous, 1976b; Cherry et al., 1978)

Dade County (Cherry et al., 1978)

Texas (Smith et al., 1964; Enkerlin, 1976; Ketner and Rosier,
 1978)

Texas (Again after eradication; Hart et al., 1973; Ketner
 and Rosier, 1978)

South America (Fig. 1)

Colombia (Russell, 1962; Weems, 1962; Angeles et al., 1967;
 Angeles et al., 1968; Bustillo, 1970; Posada and
 Garcia, 1976)

Ecuador (Yust and Cevallos, 1954-55; Russell, 1962; Jimenez,
 1963; Bennet and van Whervin, 1965; Osorio et al.,
 1972; Clausen, 1978)

Venezuela

Valera: Trujillo State, San Antonio: Tachira State
 (Angeles et al., 1967; Angeles et al., 1968)

Lara, Aragua, Monay: Trujillo (Osorio, 1970)

Tachira, Merida, Zulia, Carabobo, Miranda and Dto. Federal

(Angeles et al., 1971)

Yaracuy, Portuguesa, Falcon, Barinas (Osorio et al., 1972)

Anzoategui, Guarico, Cojedes (Angeles et al., 1974)

Atlantic Ocean Island

Azores (Russell, 1962)

Biology

Species of the genus Aleurocanthus, in common with all Aleyrodidae, are characterized by a mode of development that appears to be gradual in some respects but may be considered as of an intermediate type (Quaintance and Baker, 1913), as nymphs undergo a form of metamorphosis corresponding closely to that known as holometabolous. In consequence, the life stages are generally referred to as egg, nymph, pupa and adult (J. H. Comstock, 1967). The first description of the life history of citrus blackfly was published by S. F. Ashby in a report in the Bulletin of the Department of Agriculture, Jamaica, August 1915. Quaintance and Baker, June 1916, published the first technical description of Aleurocanthus woglumi, although they did not describe the first, second or third nymphal instars of the insect. Other authors have further described and/or photographed all stages (Dietz and Zetek, 1920; Berry and McGouch, 1932; Ebeling, 1950; Islas, 1951; Jimenez, 1963; Smith et al., 1964; Osorio, 1970; Osorio et al., 1972; and Martinez and Angeles, 1973). Many of these as well as later articles repeat material in earlier references and add little new information. The following descriptions relating to A. woglumi Ashby are basically those

published by Dietz and Zetek (1920) and prepared by Dr. A. C. Baker and Miss Margaret L. Moles of the Bureau of Entomology and Islas (1951).

Egg stage: Very minute about 0.203 mm. by 0.08 mm., elliptical in shape, curved, attached to the leaf of the host plant by a short stalk or pedicel situated near its posterior end. The eggs are normally laid in a spiral. When first laid the egg is yellowish white with reticulations on the corion, but it soon turns light brown to blackish as the embryo develops.

First nymphal instar: Elongate-ovate in shape, about 0.150 mm. by 0.304 mm., dusky in color, with reddish eye spot, short antennae, and rather short legs. On each side of a pronounced median ridge, two long dorsal spines and numerous shorter spines.

Second nymphal instar: More ovate and convex than the first stage and measuring approximately 0.200 mm. by 0.400 mm., with eye spots and vasiform orifice quite prominent. Color dull black with patches of dull green. At least 10 long spines distributed symmetrically on each side of the mesal line.

Third nymphal instar: Ovate, more convex and much larger than the second stage, averaging 0.740 mm. by 0.870 mm.; body shiny black with a more or less hemispherical dull green spot on anterior part of the dorsum, covering greater part of thorax and anterior part of the abdomen, spines are stouter with at least 13 spines symmetrically distributed on each side of dorsal line. In this instar sexes can be distinguished, the males being smaller than the female.

Fourth instar or pupa: Regularly elliptical to ovate in shape, averaging 0.89 mm. by 1.50 mm. Sexes readily distinguished, the female pupae being conspicuously larger than males, the former averaging

1.25 mm. and the latter 1.00 mm. in length. The pupa is convex with the dorsum considerably arched or rounded; the median ridge high, but not markedly distinct from the dorsal area, except near the caudal portion of the abdomen and at the vasiform orifice, which is elevated into a more or less prominent tubercle. Color shiny black with at least 15 spines on either side of the dorsal mesal line. These vary considerably in length, but the caudal pair is nearly always the longest. Margin of the pupal case dentate, teeth large and bluntly rounded. Spaces between teeth not acute, but often quadrate. A space of 0.1 mm. is occupied by 6 or 7 teeth. On this feature alone the pupal case is easily separable from those of the other species. The pupa has a marginal band of white waxy secretion, males usually secreting noticeably more than females. The cottony lateral wax fringe sometimes extends mesad, irregularly covering the submarginal area, but the secretion is usually absent dorsally.

Adult stage: When the adult emerges, the head, thorax, and abdomen is a bright brick-red in color, with front of head (vertex) pale yellow, antennae and legs whitish, and eyes a deep red or reddish brown. Later the head, thorax, wings (with the exception of the colorless or whitish areas), and legs dusky pale, suture of thorax smoky; the entire abdomen remains a brick-red color and the antennae more or less whitish, tinged with pale yellow. Eyes become a deep reddish brown. The insects become covered with heavy pulverulence so that they have a general slaty blue appearance. When the insects are at rest, the colorless spot on the wings form what appears to be a white band across the middle of the abdomen. Adult females average 1.66 mm. and males 1.33 mm. in length. Adult males resemble the females but

are smaller and the more slender abdomens bear a pair of terminal claspers.

A more complete technical description can be found in Dietz and Zetek, 1920, pages 39-42.

All nymphal instars except the first are scale-like, and appressed to the leaves. The first instar is a crawler that inserts its mouth-parts into the leaf along the minor venation and usually becomes stationary within ca. 15 minutes after emergence. However, on more mature leaves a nymph may continue its search for a favorable feeding station for as long as 24 hours after hatching (Sanchez et al., 1977) (45 to 60 minutes, Islas, 1951). Dowell et al. (1978) found that a small portion (0.2-0.3%) of first instar A. woglumi is mobile for 2-4 hours and will crawl up to 25-30 mm. Earlier Dietz and Zetek (1920) observed crawlers to move a maximum distance of 38 mm. from the egg spiral (5 to 10 mm., Islas, 1951). Islas (1951) states that the time required for a crawler to settle depends upon the maturity of the leaf. He also observed a 2 day old crawler moving from one site to another on the same leaf. On new leaves the mobility time is reduced.

Life History

In the laboratory egg laying begins approximately 18 hours after emergence of adults, and may continue for as long as 4 (or more) days in adults of unknown history brought in on young citrus shoots (Dietz and Zetek, 1920); however, Sanchez et al. (1977) found egg deposition to cease after 3 days when females were confined in a cage. It has been observed that females will lay eggs near the pupal cases from which they have emerged. Copulation takes place on the young growth where both

sexes congregate to obtain food and to insure fertilization of the females. Mating has been observed between individuals whose color would indicate that they were not more than 12 hours old (Dietz and Zetek, 1920). The females oviposit usually in a spiral pattern on the underside of leaves on the same day mating takes place. Males are polygamous, but no multiple mating of the females has been observed (Sanchez et al., 1977). However, Dietz and Zetek (1920) observed a male that mated with the same female 3 times in 20 minutes. Islas (1951) observed that the elapsed time between 2 matings of a couple was 60 seconds. In laying eggs the female usually starts at what becomes the center of the spiral. Each female oviposits from 35 to 50 eggs per spiral (50 eggs per spiral, Ashby, 1915) and more than one spiral is laid per female; thus a single female may lay considerably more than 100 eggs in her lifetime (Dietz and Zetek, 1920; Jimenez, 1963 and Smith et al., 1964). According to Sanchez et al. (1977) the usual number of eggs per spiral ranged from ca. 20-40 and each female blackfly was observed to deposit an average of 61 eggs during the first 3 days of life. Females lived as long as 13 days. It may be assumed that the life of the adults is at least a week and that it may be as long as 12 days (Dietz and Zetek, 1920) (1 to 14 days, Berry and McGough, 1932). Jimenez (1963) and Smith et al. (1964) stated that mating takes place soon after emergence, and oviposition occurs several days later.

Hatching occurs in from 9 to 40 days according to the weather (9 to 25 days, Jimenez, 1963; and Smith et al., 1964) (11 to 20 days, Dietz and Zetek, 1920) (12 to 40 days, Berry and McGough, 1932) (14 days, Ashby, 1915; and Sanchez et al., 1977) (15 to 29 days, Osorio et al., 1972).

The first molt occurs in from 6 to 43 days (Berry and McGough, 1932) (7 to 16 days, Dietz and Zetek, 1920) (8 to 17 days, Jimenez, 1963; and Smith et al., 1964) (9.5 days, Sanchez et al., 1977 and 10 days, Ashby, 1915) (7 to 11 days, Islas, 1951). The second molt occurs in from 4 to 30 days (Berry and McGough, 1932) (3 to 13 days, Dietz and Zetek, 1920) (7 to 16 days, Jimenez, 1963; and Smith et al., 1964) (7 days, Sanchez et al., 1977; and 8 days, Ashby, 1915) (5 to 11 days, Islas, 1951). The third molt occurs in from 7 to 31 days (Berry and McGough, 1932) (8 to 14 days, Dietz and Zetek, 1920; Islas, 1951) (7 to 22 days, Jimenez, 1963; and Smith et al., 1964) (9.5 days, Sanchez et al., 1977; and 11 days, Ashby, 1915) before becoming a pupa. Pupal molt occurs in from 16 to 89 days (16 to 48 days, Dietz and Zetek, 1920) (18 to 89 days, Berry and McGough, 1932) (21 to 45 days, Jimenez, 1963; and Smith et al., 1964) (22 days, Sanchez et al., 1977; and Ashby, 1915) (22 to 35 days, Islas, 1951). The period between molts seems to be determined by temperature and according to Berry and McGough (1932), developmental periods of each stage doubles with a temperature reduction of 4.44°C (8°F) to 6.66°C (12°F). The life cycle from egg to adult may, therefore, range from 42 to 233 days (1.4 to 7.77 months), a great variation being noted even among eggs laid on the same leaf on the same day but in different egg spirals (45 to 113 days, Dietz and Zetek, 1920) (54 to 144 days, Berry and McGough, 1932) (60 to 120 days, Jimenez, 1963; and Smith et al., 1964) (62 days, Sanchez et al., 1977; and 63 days, Ashby, 1915) (45 to 127 days, Islas, 1915). Dowell and Fitzpatrick (1978) working with thermal units found that the life cycle varies from 66.8 days at 28.4°C to 156 days at 20°C.

On the basis of the maximum and minimum times for the completion of the life cycle from egg to adult there is the possibility of from three to six generations per year with all degrees of generation overlapping even from the same colony of individuals.

Morrill (1903) was the first to note parthenogenesis in this family, and Morrill and Back (1911) further established the phenomenon in D. citri. Parthenogenesis occurs in A. woglumi (Dietz and Zetek, 1920) when unfertilized eggs hatch and the nymphs develop into adult males, a condition known as arrhenotoky.

Host Plants

The citrus blackfly is a highly polyphagous insect and will oviposit on at least 160 plant species in 60 families (Dietz and Zetek, 1920; Shaw, 1950a; Anonimo, 1952; Angeles et al., 1972; Hill, 1975; Howard and Neel, 1977; Steinberg et al., 1978; Howard, 1979; Dowell and Steinberg, 1979; Dowell et al., 1979). There is, however, little relation between the number of plant species on which eggs have been found and the number on which immature stages can develop. Plant attractiveness appears innate and is unrelated to the frequency with which the plant occurs in the environment. Dowell et al. (1979) found that mango (Mangifera indica L.: Anacardiaceae), pink trumpet (Tabebuia pallida (Lindley) Miers: Bignoniaceae) and kumquat (Fortunella sp: Rutaceae) are as attractive as Citrus (Rutaceae) to ovipositing A. woglumi at low densities. They found that citrus blackfly adults appear to be attracted to plant material reflecting light in the 500-600 nm. range. This indicates that blackfly females do not oviposit on plants at random but appear to actively seek "preferred"

host plants. On the other hand, the number of host species utilized for oviposition and development is a function of the size of the citrus blackfly population (Jimenez, 1963; Smith et al., 1964; Howard and Neel, 1977; Dowell et al., 1979). Dowell (1979a) states that dispersal from the leaf upon which the insect develops occurs if the leaf is unacceptable for feeding or after oviposition and that host discrimination occurs only after the females makes physical contact with the plant. In its area of origin the citrus blackfly has been reported only from Citrus spp.; however, in the Western Hemisphere the number of "preferred" host plants on which A. woglumi is reported to oviposit and develop is remarkably large. Dowell and Steinberg (1979) tested 23 plant species for development and survival of immature citrus blackfly and found that survival was not closely related to either plant family or plant species and that number of degree-days required for completion of the insect's life cycle did not vary significantly among the plants. Survivorship of A. woglumi on lemon is significantly higher than that on orange, lime, tangerine and tangelo which are not significantly different from each other, while survivorship on grapefruit is significantly lower (Dowell et al., 1978). Three factors interact to determine the importance of any host plant. Females must frequently oviposit upon the plant, substantial numbers of nymphs must complete development, and the plant must be commonly found in the environment (Dowell and Steinberg, 1979). Clausen found during two years of observation in seven asiatic countries that citrus was virtually the sole host of citrus blackfly (Clausen and Berry, 1932). However, noncitrus host plants are important as aids to dispersal of A. woglumi.

Damage or Injury

Damage caused by the citrus blackfly results from feeding, particularly on new growth of the host plants and from excretion of honeydew on which sooty-mold fungus develops (Ashby, 1915; Dietz and Zetek, 1920; Berry and McGough, 1932; Russell, 1962; Jimenez, 1963; Smith et al., 1964; Angeles et al., 1971; Osorio et al., 1972; Hart et al., 1976; and Cherry et al., 1978). Badly infested leaves wither and drop off as a result of injury caused by extraction of the cell sap. Such defoliation weakens the tree, interferes with its normal development and fruiting, and makes it unsightly (Clausen and Berry, 1932; Berry and McGough, 1932; Russell, 1962; Jimenez, 1963; Osorio et al., 1972; Enkerlin, 1976). Hart et al. (1976) state that damage to citrus foliage caused by A. woglumi is of two types: feeding injury which results in damage to cells of the lower epidermis, due to thickening of the cell wall, loss of cellular contents and the appearance of chlorotic areas on leaves, and the physiological damage caused by a sooty-mold fungus (Capnodium citri Berk. and Desm.) that develops on the honey-dew excreted by the developing insect. Sooty-mold deposits reduce the photosynthesis and respiration of the affected plant. In Mexico there is almost a complete crop failure when heavy infestation of the citrus blackfly lasts longer than one year (Jimenez, 1963; Smith et al., 1964; and Enkerlin, 1976).

Biological Control in the Western Hemisphere

Introduction of natural enemies from Asia for control of the citrus blackfly in Western Hemisphere countries can be divided into 2 stages.

The first, in 1930, began with the shipment of Eretmocerus serius Silv. from Malaya. In 3 consignments of natural enemies forwarded from Malaya during 1930 and 1931 Prospaltella divergens Silv., P. smithi Silv., Cybocephalus sp., Catana clauseni Chapin (Cryptognatha sp.), Scymnus smithianus Silv., Scymnus sp. near pallidicollis Mulsant, and Acletoxenus indica Malloch were present in varying numbers (Clausen and Berry, 1932; Bruner, 1954).

Of the natural enemies listed above, E. serius, C. clauseni and S. smithianus were established in Cuba. Scymnus smithianus was apparently not well adapted to Cuban conditions. Catana clauseni demonstrated ability to suppress heavy citrus blackfly infestations but became inactive in low or moderate infestations and failed to prevent resurgence to high levels. This predator was also released in the Bahama Islands to supplement the activity of E. serius. Of the species successfully established in Cuba during the first period only E. serius proved useful. Commercial control of the citrus blackfly was quickly obtained throughout Cuba. This parasite was later introduced into other countries of the Western Hemisphere (Clausen and Berry, 1932; Bruner, 1954).

The second stage of natural enemies importation began in November 1949 with shipment of parasitized material from India and Pakistan to Mexico. Shipments were terminated in April 1950. Amitus hesperidum Silv., Encarsia merceti Silv., Eretmocerus serius, Prospaltella clypealis, P. divergens, P. opulenta, P. smithi, Prospaltella sp. (near citrofila Silv.), Catana parcesetosa (Sicard), and Acletoxenus indica were included in the shipments received during this period (Jimenez, 1963; Smith et al., 1964).

Amitus hesperidum, P. opulenta and P. clypealis proved to be the most effective species in the control of the pest in México (Jimenez, 1963; Smith et al., 1964).

A more comprehensive discussion of the natural enemies and of their introduction into the countries of the Western Hemisphere known to be infested with citrus blackfly follows.

Amitus hesperidum Silvestri (Hymenoptera: Platygasteridae)

Amitus hesperidum is biparental in reproduction with a sex ratio 1:1. There is 1 generation for each generation of the host.

The female is proovigenic, and as an adult lives from 3 to 6 days under favorable conditions. According to Dowell (1979b), A. hesperidum lived an average of 2 days without food or water, 2.3 days with water only and 4.1 days with 1:1 mixture of honey:water.

Mating occurs readily, the male having emerged from the host a few days ahead of the female. Oviposition by A. hesperidum occurs in the 3 nymphal instars of citrus blackfly, with an apparent preference for the first. Thirty eggs, presumably nonpolyembryonic, may be deposited in rapid succession. One to 3 eggs are deposited in a single host, each egg being placed in the host's midgut. Female host pupae commonly produce 2 and occasionally 3 parasites, whereas male host pupae produce only 1. Host pupae usually enlarge perceptibly, and this occurs while A. hesperidum is still in the minute first larval instar. The parasite larva completes its development only after the host attains an advanced stage. The emergence holes of the adult parasites are usually in the side of the vacated host rather than on its ends (Jimenez, 1963; Smith et al., 1964; Flanders, 1969).

Eretmocerus serius Silvestri (Hymenoptera: Aphelinidae)

The first shipment of E. serius Sil. from Malaya to Cuba was made in March 1930 (Bruner, 1931; Clausen and Berry, 1932). This parasite was responsible for the first example of successful use of parasites for control of citrus blackfly in the Western Hemisphere (Clausen and Berry, 1932; Bruner et al., 1945; Osorio, 1946; Shaw, 1950b; Bruner, 1954). This proovigenic species reproduces biparentally. The life cycle of the male is normally about 2 days shorter than of the female. The sex ratio is about 1 male to 1.99 females. Mating takes place on the foliage very shortly after emergence, and oviposition may ensue the same day. Oviposition continues over a period of 7 to 10 days. It completes development as an endoparasite, but the first 2 larval instars are ectoparasitic. Oviposition may take place in any instar of the host from the first nymphal stage to pupa but is believed to prefer the second nymphal instar. Irrespective of the stage in which the eggs are laid, adults emerge from the host pupae. The complete cycle requires approximately 4 weeks; consequently, the parasite is able to develop 2 generations to each host generation. The female lays the egg on the leaf surface beneath the second nymphal instar, almost invariably in the area near the line dividing the thorax and abdomen. First and second larval instars feed externally, and although a certain amount of feeding takes place, this is considered a resting period, and the second molt is delayed until after penetration of the pupa of the host, following which development is rapid. The penetration is also usually effected in the area where the egg was placed and the entry hole is surrounded by a light brownish area that contrasts markedly with the normal black coloration of the integument.

The female does not exercise any discrimination in choice of host, and as many as 8 first and second larval instars have been found beneath a single host individual. Only 1 of these, however, can attain maturity. The body contents of the host are entirely consumed, and no solid meconium is cast by the larva. The adult parasite cuts a circular emergence hole through the dorsal integument of the anterior end of the host body (Clausen and Berry, 1932; Smith, 1945; Osorio et al., 1972).

Prospaltella clypealis Silvestri (Hymenoptera: Aphelinidae)

This species reproduces biparentally at the rate of 2 generations to 1 of its host (Flanders, 1969); however, Jimenez (1963) and Smith et al. (1964) state that it may be parthenogenetic, as mating was rarely observed.

This species is an endoparasite of citrus blackfly. The sex ratio of P. clypealis is approximately 1 to 7, with females predominating. Oviposition takes place in the 3 nymphal and pupal stages of the host, with a preference for the second instar. If oviposition takes place in the first nymphal instar, the egg is carried over into the second before hatching. The haploid (male) egg is deposited on the surface of the fully fed larva or pupae of a primary parasite of citrus blackfly. The hatched larva acts as a secondary ectoparasite feeding on developing females of its own species or 1 of like habits. Female eggs are deposited directly into the host body on the underside of the leaf. Male eggs are deposited by thrusting the ovipositor into the host body through the upper surface of the leaf (Jimenez, 1963; Smith et al., 1964; Flanders, 1969).

Flanders (1969) states that P. clypealis is synovigenic in reproduction with relative long-lived females (2 months at room temperature if fed honey). Fertilized (diploid) eggs may be deposited in the same host generation from which the female emerged. Mated females oviposit as secondary, as well as primary, parasites depending on whether a haploid or diploid egg is to be laid. As with many synovigenic species the female adults host-feed and have been observed to feed on the body fluids of first nymphal instars.

The body of the blackfly contracts somewhat in size when parasitized by Prospaltella. A host pupa from which P. clypealis has issued shows a very small emergence hole and contains a rose-colored meconium (Jimenez, 1963; Smith et al., 1964; Flanders, 1969).

Prospaltella opulenta Silvestri (Hymenoptera: Aphelinidae)

This species reproduces biparentally (Flanders, 1969). Jimenez (1963) and Smith et al. (1964) state that the life history of this species is similar to that of P. clypealis.

Prospaltella opulenta is an endoparasite of citrus blackfly. This species reproduces at the rate of 1 generation to 1 of its host. The sex ratio is about 1 to 7.3, with female predominating. According to Flanders (1969), the male of P. opulenta is an endoparasite developing as a secondary parasite of citrus blackfly through either its own species or 1 of like habits. Should such hosts of males be scarce as many as 100,000 adults of P. opulenta may be collected in the field without finding a male.

Oviposition occurs in all larval instars and the pupal stage, but the second instar is preferred. The haploid (male) egg is deposited within the host body of fully fed female larvae and pupae of

conspecifics and other primary parasites of citrus blackfly. Emergence of P. opulenta from a host pupa is indicated by a hole slightly larger than that made by P. clypealis and by a yellow meconium (Jimenez, 1963; Smith et al., 1964; Flanders, 1969).

Flanders (1969) states that P. opulenta is synovigenic with relatively long-lived females (4 to 6 weeks). After the first day of adult life ovigenesis progresses at a rate that produces 8 to 10 mature eggs a day.

Prospaltella smithi Silvestri (Hymenoptera: Aphelinidae)

This species is bisexual but reproduces uniparentally (Deuterotokous), as an endoparasite of the host pupa at the rate of 1 to 2 generations of each host generation. Mating has not been observed although the reported sex ratio of males to females is 1 to 4. The female is synovigenic with an adult life of about 1 month. She deposits diploid (female) eggs inside the Malpighian tubules of the host's pupa and late larval instar. Egg incubation period is about 3 days, but the first larval instar remains dormant until its host pupates. The haploid (male) egg develops inside the prepupa or pupa of either its own or some other parasite species, the male being a true secondary parasite of the citrus blackfly (Jimenez, 1963; Smith et al., 1964; Flanders, 1969).

Clausen and Berry (1932) state that oviposition by P. smithi takes place largely in the first larval stage of the host, though females have frequently been observed to attack the later larval stages.

Silvestri (1927) provides a complete description of the adult stages of the most important parasites of A. woglumi.

Countries of the Western Hemisphere Where Natural Enemies
Have Been Introduced for Control of Citrus Blackfly

The introduction and establishment of important natural enemies of the citrus blackfly from Malaya, India and Pakistan in Cuba and Mexico, and the further colonization and establishment of these natural enemies in other infested countries of the Western Hemisphere, is one of the outstanding successes of biological control (Fig. 1).

Cuba: Several natural enemies were sent to Cuba in 1930. They were Eretmocerus serius which multiplied to such an extent that it was possible to make liberations throughout that island and quickly obtain economic control. At the same time colonies were shipped from Cuba and the species was established in other countries. Prospaltella divergens was sent from Malaya, but no progeny developed in Cuba. Prospaltella smithi: A considerable number of this species were included in the shipments from Malaya to Cuba, but development of the parasite in the Wardian cages en route was very unsatisfactory. Cybocephalus sp. was a predator of Aleyrodidae, but no reproduction took place en route. Catana clauseni (Cryptognatha sp.) was well established at several localities in Cuba, and according to Bruner (1954) this species was still present thru May 1938 when he, Berry and Boucle collected 1,000 individuals to be sent to Bahamas. Scymnus smithianus, a coccinellid, was also established in Cuba. Scymnus sp. near pallidicollis was found attacking Aleurocanthus, but in no instance did reproduction occur. Acletoxenus indica a predacious drosophilid was received, but attempts to effect colonization failed (Clausen and Berry, 1932).

Bruner (1931) stated that of the natural enemies imported, E. serius appeared most promising. Subsequently this parasite

increased very rapidly at all sites, and commercial control was usually attained in groves 8 to 12 months after release (Bruner et al., 1945; Osorio, 1946; Shaw, 1950; Burner, 1954; Clausen, 1978). In 1945, Bruner and Boucle stated that during more than 14 years following introduction of E. serius, full control had been consistent throughout the island. Although little information is available concerning the present status of control in Cuba, there is reason to believe that at least some local outbreaks of the citrus blackfly have occurred. Reasons for such outbreaks are conjectural but possibly a result of host resistance to E. serius or adverse factors of climate. In any event, Sailer (1976a) learned that P. opulenta was shipped to Cuba from Mexico in September 1976.

Panama (including Canal Zone): According to Clausen and Berry (1932), James Zetek, in charge of the Bureau of Entomology Laboratory at Balboa, Canal Zone, rendered valuable assistance in the preparation for the second trip to Malaya, 1930, and was responsible for the colonization and establishment of Eretmocerus serius in Panama. They add that colonies of E. serius were also sent from Cuba to the Canal Zone, the Bahamas and Haiti. Clausen (1978) also states that this parasite was introduced from Cuba into the Panama Canal Zone, Haiti and the Bahamas Islands in 1931. Zetek in official correspondence informed Shaw (1950b) that E. serius effected commercial control of the citrus blackfly in Panama.

Haiti: Dozier (1932) states that after repeated attempts to rear out a native parasite of A. woglumi in Haiti, negotiations were undertaken with the U. S. Bureau of Entomology and the Cuban Department of Agriculture to obtain a supply of E. serius from Cuba. Two shipments

were received in July and August 1931. The parasites were observed to start ovipositing immediately in several different stages of the citrus blackfly, and Dozier expressed the hope and expectation that the introduction would prove as highly successful in Haiti as in Cuba. Dozier left Haiti in 1932, and there are no later reports of progress of the parasite.

Sailer (1976b) states that in Haiti he, together with 3 other Florida entomologists, visited 3 locations where there was an appreciable amount of citrus and made several intermediate stops and examined dooryard citrus. No citrus blackfly was seen, and he was assured by Ministry of Agriculture people that the pest did not occur in Haiti. Earlier, in 1952 Miss Louise Russell, Aleyrodid specialist for the Systematic Entomology Laboratory, U.S.D.A., visited Haiti and was unable to find citrus blackfly (personal communication). If in fact the citrus blackfly has disappeared from Haiti, reasons for the disappearance should be investigated.

Bahama Islands: Clausen (1978) states that following the success of E. serius in Cuba, this parasite was introduced into the Bahama Islands in 1931. Observations by C. P. Clausen in 1937 indicated that the citrus blackfly was still abundant in places even though a high population of the parasite was present at the time. A coccinellid, Catana clauseni, previously introduced from Malaya into Cuba, was released at Nassau in the hope that it would supplement Eretmocerus in controlling infestations. It is not known whether or not the beetle became established (Richardson, 1948). The citrus blackfly is now well under control at Bahama Islands (Richardson, 1948; Clausen, 1978).

Jamaica: In April 1932 a consignment of E. serius was sent from Cuba to Jamaica (Edwards, 1932). According to van Whervin (1968), A. woglumi was under complete control over practically the whole island by 1934. In 1936, recolonization of the parasite was undertaken in some areas where E. serius appeared to have disappeared. During the 1950's recolonizations were again necessary. Because of the reduced effectiveness of E. serius during the 1950's and early 1960's it was suggested in 1964 that P. opulenta should be introduced from Mexico in an effort to achieve a higher level of control. Stock of P. opulenta was imported in September and October 1964. Successful colonization followed, and within less than 2 years this species dispersed throughout the island and almost completely replaced the previously established E. serius. There has been no recurrence of citrus blackfly infestation since introduction of P. opulenta (van Whervin, 1968; Bennett, 1971; Clausen, 1978).

Costa Rica: Eretmocerus serius was introduced into Costa Rica from Cuba in 1933-34. Commercial control followed introduction of the parasite (Clausen, 1948).

Mexico: Attempts to introduce the parasite E. serius from Costa Rica in 1936 and from the Panama Canal Zone in 1938 were unsuccessful. A further attempt was made in 1943 by United States and Mexican authorities to move this parasite from the Panama Canal Zone into Mexico (Smith, 1945). The parasite became established in at least 3 places; however, with the exception of restricted areas of persisting high humidity, it was unable to bring the citrus blackfly under satisfactory control on the west coast of Mexico (Shaw, 1950b; Jimenez, 1963; Smith et al., 1964).

Smith sent the first shipment of natural enemies of the A. woglumi from Malaya to Mexico in 1948. A few adults of P. divergens and P. Smithi emerged from the air shipment. These were released in the field but failed to become established. From November 1949 to April 1950, shipments of parasitized material were made to Mexico from India and Pakistan. Jimenez (1963) and Smith et al. (1964) give a list of the various species of natural enemies of the citrus blackfly that emerged from these shipments and were released in infested citrus groves. Three of these parasites, Amitus hesperidum, Prospaltella clypealis and P. opulenta have become dominant in controlling the citrus blackfly in Mexico. The native predator Delphastus pusillus is useful in reducing heavy infestations, but it cannot be depended on to effect satisfactory control in the absence of parasites.

Prospaltella smithi appeared to be the most promising of the imported parasites during the early stages of the program. It proved to be dominant over Eretmocerus but was in turn superseded by P. opulenta, P. clypealis and A. hesperidum. While both species have persisted in Mexico, they are seldom present in detectable numbers (Smith, 1958; Jimenez, 1963; Smith et al., 1964).

Smith (1958), Jimenez (1963), Smith et al. (1964) and Flanders (1969) studied the interrelations and the competition between the natural enemies of the citrus blackfly in Mexico.

The most effective of the imported parasites were P. opulenta, P. clypealis and A. hesperidum. The former is adapted to a wider range of climate than the other two and is much more effective in the hot dry regions of the country, whereas the second is best adapted to humid conditions. Amitus hesperidum is especially effective when released

in heavy infestations, but its numbers are reduced when in competition with either of the 2 Prospaltella (Clausen, 1978).

According to Jimenez (1971), P. opulenta and A. hesperidum are now the most effective parasites for the control of A. woglumi and P. clypealis, P. smithi and E. serius are of little importance as factors responsible for control of the citrus blackfly in Mexico.

No commercial damage has been reported in recent years from any area of Mexico; however, it has been necessary periodically to recolonize certain areas. This is accomplished by moving parasites from areas where they are abundant to areas where they have disappeared because of climatic irregularities, drift of insecticides applied to crops near citrus groves, or for reasons not well understood (Smith, 1958; Jimenez, 1963; Smith et al., 1964; Anonimo, 1964; Jimenez, 1970; Jimenez, 1971; Enkerlin, 1976).

Barbados: According to Bennett and van Whervin (1966), adults of E. serius and leaves bearing parasitized citrus blackflies were collected in Jamaica by Bennett during June 1964. The adults and those subsequently emerging from the infested leaves were released on heavily attacked trees in several areas in Barbados. Establishment was attained and extensive spread was noted. Arrangements were made to obtain shipments of P. opulenta from Mexico in late 1964 and early 1965. This species also became established, and the citrus blackfly was quickly reduced to nonpest status (Bennett and van Whervin, 1966; Pschorn-Walcher and Bennett, 1967; Bennett, 1971).

Ecuador: Anitius hesperidum was imported into Ecuador in 1955 and is reported to be established. The effectiveness of this parasite has not been reported (Clausen, 1978).

El Salvador: Small shipments of P. opulenta from northern Mexico and Barbados were secured in 1970, but there was no evidence of the establishment of the released parasite. In July 1971, P. opulenta was brought from Mexico and the parasite was soon well established. Another shipment of parasites from Mexico was secured in April 1972.

Aleurocanthus woglumi is under biological control in El Salvador (Quezada, 1974), except in citrus groves near or surrounded by cotton fields (Sailer, personal communication).

U.S.A.: The citrus blackfly appeared the first time in Key West Island, Florida, in 1934. This infestation was successfully eradicated in 1937 as a result of a spray program (Newell and Brown, 1939). The second infestation of citrus blackfly, A. woglumi, was found in Texas in 1955. Chemical applications were made and eradication was achieved by 1956 (Cavin, 1976; Ketner and Rosier, 1978).

According to George Cavin (1976), in 1966, Hurricane Beulah came up from the Yucatan Peninsula into Mexico. Within 6 to 7 months after the hurricane, they began finding the citrus blackfly in citrus groves, and in 1967 an infestation was well established in the lower Rio Grande Valley of Texas. Subsequent eradication efforts failed.

By 1971 the infestation included Brownsville, and other areas of the lower Rio Grande Valley have since been invaded (Cavin, 1976; Ketner and Rosier, 1978).

In 1974, an area of Brownsville was set aside for integrated control. Prospaltella opulenta from Mexico was released, and the parasites became established. The success of the biological control program is evidenced by the absence of documented production losses in commercial groves due to citrus blackfly infestations during the 1976 and 1977 crop years (Ketner and Rosier, 1978).

In January 1976, Aleurocanthus woglumi was discovered in Fort Lauderdale, Florida. Immediate action was taken by Florida State and Federal Regulatory agencies to contain the infestation through imposition of quarantine measures. This was quickly followed by a program designed to eradicate the infestation. Initially, plans for introduction of parasites were made with the view that they might reduce the population of citrus blackfly and facilitate eradication. During April 1976 and continuing through the summer, shipments, which included 3 species of parasites, were sent to Fort Lauderdale. These were provided by the U.S.D.A. Laboratory at General Teran, Mexico, where the 3 species were in culture. Of the 3 species, A. hesperidum, P. opulenta and P. clypealis, A. hesperidum was released in largest numbers and was responsible for reduction of the population to about 3% of the prerelease level. At this point P. opulenta, which was released at the same time but in much smaller numbers, began to increase and by the end of 1979 was the dominant parasite in the infested area. The third species, P. clypealis, was released in very small numbers and has not been recovered (Hart et al., 1978; Dowell, 1979b; Dowell et al., 1979; Dowell et al., 1980).

Dowell et al. (1979) state that for the period of May 1977-December 1978, citrus blackfly was under complete biological control in southern Florida due to the combined action of A. hesperidum and P. opulenta.

Venezuela: The first report of Aleurocanthus woglumi in Venezuela was made by Angeles et al. (1967) from specimens collected in Cucuta (Colombia) and San Antonio del Tachira (Venezuela) on leaves of Citrus sinensis and identified by Louise Russell of the U. S. Department

of Agriculture (Fig. 2). Specimens closely resembling those identified by Russell were collected in 1965 at Valera, Trujillo State (Venezuela).

Osorio (1970) and Osorio et al. (1972) state that the citrus blackfly first came to the attention of the Department of Entomology of the Universidad Centro Occidental in 1968. It seems that A. woglumi has been established in Barquisimeto (Lara State) since 1966 or 1967, and that its introduction was possibly through Colombia from Ecuador or Central America. It might also have been inadvertently introduced directly from some country of the Western Hemisphere where the citrus blackfly was already established.

Later, Angeles et al. (1971), Osorio et al. (1972), Angeles et al. (1972), Martinez and Angeles (1973), Angeles et al. (1974) contributed substantially to the knowledge of the distribution, biology, host plant, native enemies (parasites, predators and fungus diseases), and control. Osorio et al. (1972) suggested importation of natural enemies as the only solution to suppression of the pest.

In October 1975, a team consisting of entomologists of the U.C.V. (Facultad de Agronomia), C.E.N.I.A.P. and FUSAGRI who had previously been trained by the Division de Control Biologico de la Direccion General de Sanidad Vegetal de Mexico and subventioned by the CONICIT and the Direccion de Sanidad Vegetal del M.A.C., received the first shipments of parasites from Mexico. These parasites, Prospaltella opulenta, were released in Aragua and Yaracuy States but no establishment was obtained. Approximately 120,000 adult P. opulenta were included in the shipment, and failure to establish may have been due to their being held at the customhouse for 2 days during which average mortality was 50%. After processing through quarantine,

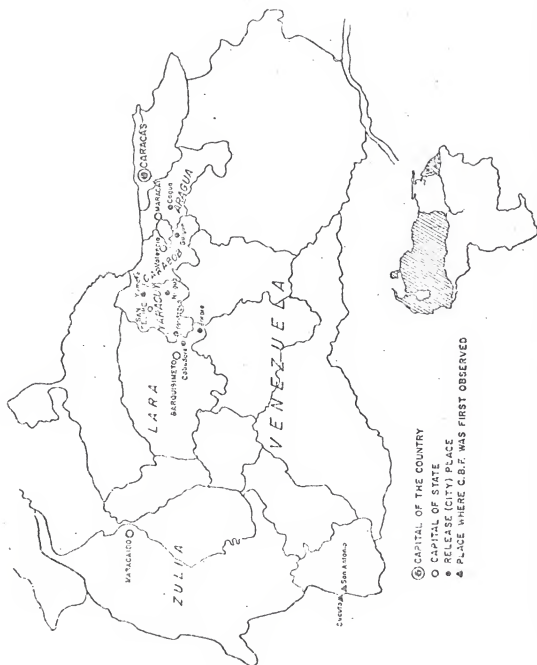


Figure 2. Places where P. opulenta has been released in Venezuela and where A. woglumi was first observed.

only 20,000 parasites were available for release in the field. The releases coincided with the season of heavy rain when the citrus blackfly populations normally declined due to fungus diseases (Geraud et al., 1977; Geraud, 1979).

A second series of parasites shipments was received in June 1976. These parasites (40,000 approx.) were released directly in the field in Aragua, Carabobo and Yaracuy States. According to Geraud et al. (1977) and Geraud (1979), positive evidence of establishment between June and September of the same year was found.

CHAPTER III
BIOLOGICAL CONTROL OF CITRUS BLACKFLY IN THE
CENTRAL-WESTERN REGION OF VENEZUELA

Lara State encompasses 4 markedly different regions, the foothills of the Andes Mountains on the south and the Coastal Range on the north. The western part is semiarid and the eastern area is typical of the Venezuelan Llanos. As a consequence, there are a variety of climatic conditions that contribute to a diversity of crops and animal breeding that makes Lara State one of the most important agricultural areas in Venezuela and an important market center for agricultural and livestock products. Although citrus is not as important as other crops, it constitutes one of the most important fruit processing industries. Juconasa is located at Cabudare city (Lara State) where most of the citrus fruit harvested in the central and central-western regions are processed as frozen concentrates and chilled pasteurized juice. In addition, dooryard citrus is very common in residential areas of the highly urbanized cities as well as in farmsteads in rural areas. These trees were generally infested throughout the state and provided additional justification for the introduction of P. opulenta from Carabobo State (Venezuela), where by 1976 it could be easily obtained.

Materials and Methods

Host Plants

Citrus trees were selected in accord with the importance of the commercial variety. Three varieties were sampled: "California" in Santa Lucia orchard, "Pineapple" in Apoliro orchard and "Valencia" in Glorida de Lara orchard. All the citrus trees sampled were about 12 years old.

Locations

Citrus blackfly populations were sampled every 2 weeks at 3 locations, the first being located in the Hacienda Santa Lucia (Yaritagua: Yaracuy State). This citrus grove occupied an area of 7,884 m² and contained 259 trees. It is located in a sugarcane farm, and it is not managed in a manner similar to commercial groves. These trees received no pesticide treatments but may have received some drift from treatments applied to the nearby sugarcane; however, such treatments are seldom applied on this particular farm.

The other 2 locations were the Apoliro Experimental Orchard (Juconasa Industries) in which the study area was 119,280 m² with 2,635 citrus trees located close to Cabudare city (Lara State), and the Glorida de Lara in which the study area was 78,800 m² with 2,045 citrus trees, located close to Sarare city (Lara State) (Fig. 2). Both are managed as commercial groves, and much of the land surrounding the study groves is also planted to citrus.

In all 3 of the study groves no pesticides were applied during the period of study.

Sampling Procedure

Five citrus trees were sampled in each location. Each tree was divided in 4 quadrants: north, south, east and west; in each quadrant a new, middle, and old leaf was taken and placed separately in a previously labeled small plastic bag. Samples from different trees were held separately, and the same trees were sampled throughout the period of observation.

One sample was taken each 2 weeks from each tree from November 1976 through November 1977 (see solid line in the figures 4-27). Additional samples were taken during January, February, April and June 1978 and February 1979 from the "Apoliro" and "Santa Lucia" citrus groves and during January, February and June 1978 and March 1979 from the "Gloria de Lara" citrus grove (see dashed line in the figures 4-27).

A "new leaf" was the third leaf of the new flush, or, in the absence of new flush, the "new leaf" was the second leaf of the last "flush" season. The middle leaf was either the third or fifth leaf of the last "flush." Old leaves were taken from leaves of the past year's growth. Branches from which leaves were taken were selected at random within each quadrant and height range of between 1.50 m. to 2.0 m. as previously used by Chavez (1974).

Count

Each leaf was placed under stereoscopic microscope Olympus (10x) for the purpose of counting numbers of eggs, nymphs (first, second and third instar), pupae and exuviae. A 10x power magnification was used as this is the normal magnification of a good hand magnifier used for assessing the pest in the field.

Adults were counted in the field at the time leaf samples were taken.

All samples were counted on the basis of 2 square centimeters in the center of the leaf. Full leaf counts were also made of the same leaves as a check on reliability of the 2 square centimeter counts.

Mortality Factors

Insofar as possible, causes of mortality were identified in the field as well as in the leaf samples collected for count of immature stages. Insects were identified by comparison with identified reference specimens in the Entomological Museum of the Universidad Centro Occidental Lisandro Alvarado, Escuela de Agronomía, as well as with specimens in possession of Ing Agr. Nancy de Martínez (CENIAP--Maracay). Identifications were confirmed by specialists of the U.S.A. and Israel (Martínez, 1978).

Statistical Analysis

Data from the 2 square centimeter counts were subjected to simple correlation analysis as well as a regression analysis including the linear and quadratic effect as required for establishing a prediction equation based on the value of r for each citrus orchard separately.

Parasite

Specimens of Prospaltella opulenta were collected in the "La Segoviana" citrus orchard (Guigüe: Carabobo State) (Fig. 2) on April 22, 1977, with a double chamber aspirator. Approximately 100 parasites were placed in vial, each of which contained a piece of filter paper saturated with a 1:1 mixture of honey and water. The parasites were collected in the morning and hand carried to expedite

delivery and insure maximum survival. Parasites were received in the afternoon, immediately carried to the field and released directly on the underside of leaf surfaces in heavily infested trees by uncapping and inverting the vials.

Two hundred parasites were released at "Santa Lucia" and 800 at "Apoliro." One hundred parasites were released on each tree, and no release trees were used for subsequent leaf samples. This was to insure no interference with the establishment and colonization of the small number of P. opulenta released.

First and second nymphal instars of citrus blackfly, the preferred instar for parasitism by P. opulenta, were abundant at the release sites at the time of release. The average mortality of adult parasites shipped ranged between 1 and 3%.

Evaluation of the parasites were made by counting the pupae with parasite holes and by dissection of pupae and third instars to determine whether parasite larvae or pupae were present.

Results

Hacienda Santa Lucia

This citrus grove contained 259 trees in an area of 7,884 m² (Fig. 3) and received no pesticide treatments, but some drift of pesticide could have reached the trees from the surrounding areas where the pesticides were applied to control sugarcane pests. Figures 4 and 5 show the population trends of citrus blackflies at Santa Lucia citrus grove. Figure 4 shows clearly the 5 generations of A. woglumi through a year of study from November 1976 to November

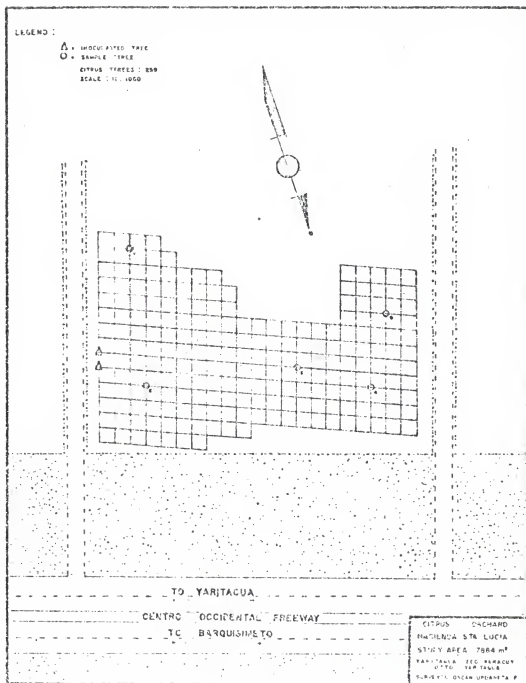


Figure 3. Hacienda Santa Lucia, Yaritagua.

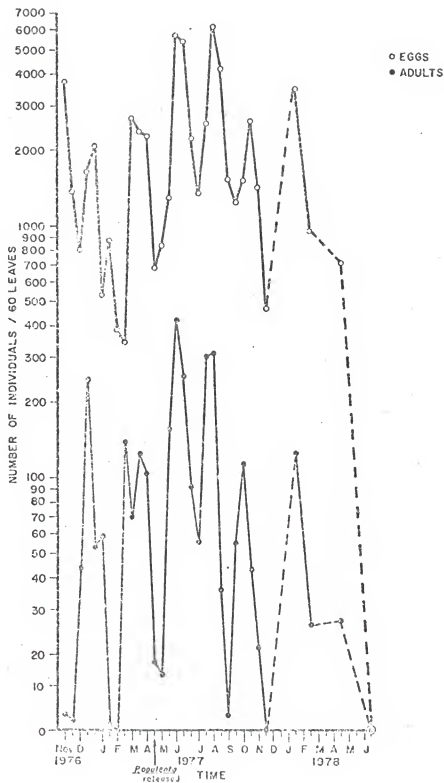


Figure 4. Egg and adult populations of *A. woglumi* observed on leaves of *C. sinensis* var. "California" at Hacienda Santa Lucia, Yaritagua. (For explanation of dashed line, see page 38.)

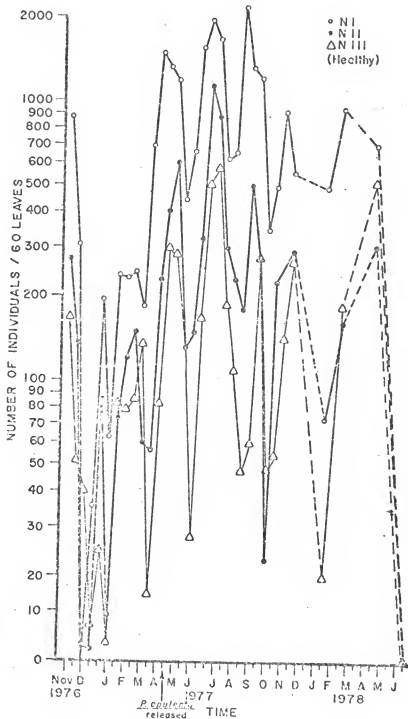


Figure 5. First, second, and third nymphal instars of *A. woglumi* observed on leaves of *C. sinensis* var. "California" at Hacienda Santa Lucia, Yaritagua. (For explanation of dashed line, see page 38.)

1977. Those generations were the first in December, the second at the end of February and early March, the third in June, the fourth at the end of July and early August, and the fifth in October. Figure 5 shows the peaks of each of the nymphal instars and the shift from 1 nymphal instar to the next.

Figures 6, 7, and 8 show the population trends of each nymphal instar and the number of total, healthy and dead individuals for each sample date. As is evident from the data preceding release of P. optulenta on April 22, 1977, the mortality factors (biotic and abiotic) did not prevent resurgence of citrus blackfly population despite a decline that occurred in December 1976 when samples showed 100% mortality of first instars, 95% of seconds and 70% of the third stage (Table 1). Dead individuals of all developmental stages had the appearance of individuals killed by fumigation or by some sprays. However, individuals that are victims of sucking predators and parasite host feeding as well as those "stung" by female parasites but not successfully parasitized have this same appearance. This has been referred to as unexplained mortality (Morrill and Back, 1912; Chavez, 1974; Sailer, personal communication; Dowell, personal communication). During this time, precipitation was low (Fig. 9 and Table 2); however, relative humidity was comparatively high (76%) and the leaves were regularly covered by morning dew which favored the development of fungus diseases (Aegerita webberi Faw. and Aschersonia aleyrodis Webber). Several adults were observed to be trapped in dew drops. Other natural enemies found in higher numbers during December were Mantispidia sp. near viridis Walk (Neuroptera: Mantispidae) and Nodita sp. (Neuroptera: Chrysopidae) and the most important were

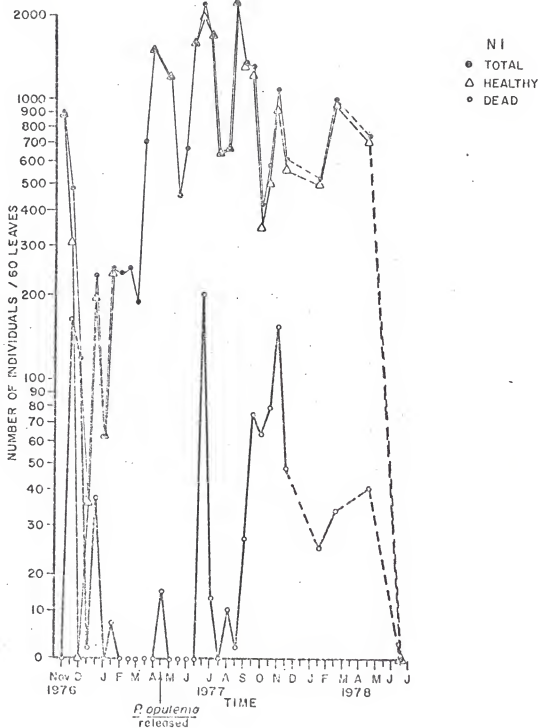


Figure 6. Total, healthy, and dead first nymphal instar populations of *A. woglumi* observed on leaves of *C. sinensis* var. "California" at Hacienda Santa Lucia, Yaritagua. (For an explanation of dashed line, see page 38.)

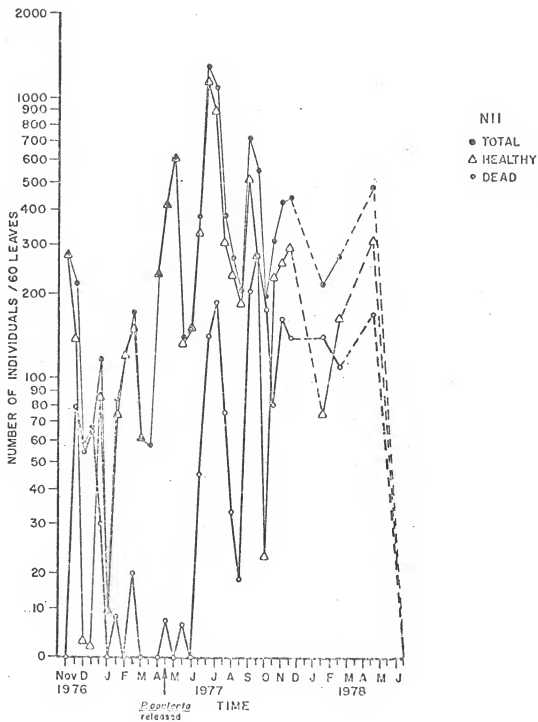


Figure 7. Total, healthy, and dead second nymphal instar populations of *A. woglumi* observed on leaves of *C. sinensis* var. "California" at Hacienda Santa Lucia, Yaritagua. (For an explanation of dashed line, see page 38.)

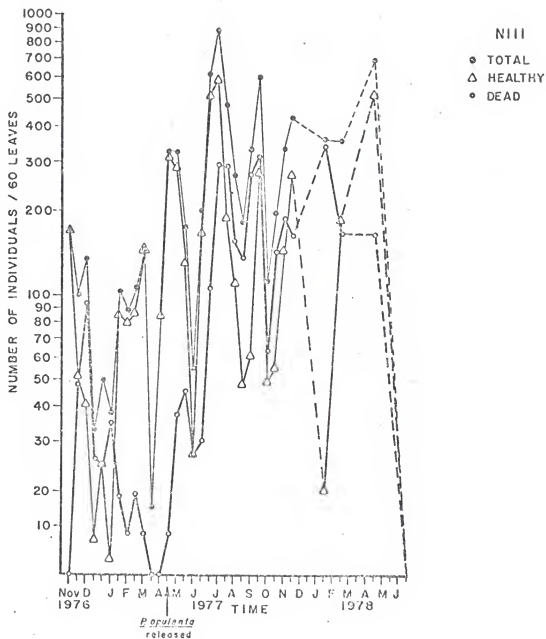


Figure 8. Total, healthy, and dead third nymphal instar populations of *A. woglumi* observed on leaves of *C. sinensis* var. "California" at Hacienda Santa Lucia, Yaritagua. (For an explanation of dashed line, see page 38.)

TABLE 1

PERCENT HEALTHY AND DEAD NYMPHS OF A. WOGLUMI ON 60 SAMPLED LEAVES PER DATE
LOCALITY: YARITAGUA (HACIENDA "SANTA LUCIA")

Date	Nymph I			Nymph II			Nymph III			% Infested Leaves ¹	Infestation Index ²
	Total	% Healthy	% Dead	Total	% Healthy	% Dead	Total	% Healthy	% Dead		
11/11/76	889	100.00	0.00	276	100.00	0.00	172	100.00	0.00	48.33	90.55
11/13/76	477	65.20	34.80	216	63.43	36.57	100	52.00	48.00	28.33	32.27
12/02/76	120	0.00	100.00	57	5.26	94.74	134	30.60	69.40	26.67	15.25
12/16/76	38	94.74	5.26	66	3.03	96.97	33	21.21	78.79	33.33	29.93
12/30/76	236	83.90	16.10	116	74.14	25.86	50	50.00	50.00	35.00	42.95
01/13/77	64	100.00	0.00	9	100.00	0.00	38	7.89	92.11	26.67	10.27
01/27/77	250	97.20	2.80	82	90.24	9.76	103	82.52	17.48	23.33	21.33
02/11/77	239	100.00	0.00	122	100.00	0.00	88	90.91	9.09	25.00	15.70
02/25/77	250	100.00	0.00	171	88.30	11.70	106	82.08	17.92	33.33	17.70
03/10/77	188	100.00	0.00	61	100.00	0.00	146	94.52	5.48	40.00	54.55
03/24/77	704	100.00	0.00	57	100.00	0.00	15	100.00	0.00	35.00	54.33
04/11/77	1515	100.00	0.00	233	100.00	0.00	84	100.00	0.00	40.00	69.17
04/21/77	1359	98.90	1.10	414	98.31	1.69	325	97.54	2.46	45.00	47.42
05/05/77	1213	100.00	0.00	612	100.00	0.00	325	88.62	11.38	51.67	50.48
05/19/77	451	100.00	0.00	138	95.65	4.35	175	74.29	25.71	48.33	43.20
06/02/77	668	100.00	0.00	150	100.00	0.00	55	51.00	49.00	63.33	116.32
06/16/77	1585	100.00	0.00	376	88.03	11.97	201	85.07	14.93	68.33	125.18
06/30/77	2199	90.86	9.14	1281	83.99	11.01	620	83.06	16.94	75.00	98.53

TABLE 1--Continued

Date	Nymph I			Nymph II			Nymph III			% Infested Leaves ¹	Infestation Index ²
	Total	% Healthy	% Dead	Total	% Healthy	% Dead	Total	% Healthy	% Dead		
07/14/77	1668	99.23	0.77	1079	82.85	17.15	884	67.08	32.92	58.33	80.85
07/23/77	637	100.00	0.00	378	80.16	19.84	477	40.04	59.96	63.33	72.95
08/11/77	673	98.51	1.49	265	87.55	12.45	266	41.73	58.27	53.33	125.23
08/25/77	2224	99.91	0.09	201	91.04	8.96	183	26.23	73.77	60.00	112.08
09/08/77	1352	98.00	2.00	716	71.65	28.35	331	18.43	81.57	61.67	61.43
09/22/77	1308	94.27	5.73	545	49.91	50.09	600	46.00	54.00	56.67	52.97
10/06/77	415	84.58	15.42	196	11.73	88.27	112	43.75	56.25	41.67	34.92
10/20/77	580	86.38	13.62	307	73.94	26.06	197	27.92	72.08	38.33	56.12
11/03/77	1083	85.78	14.22	420	61.43	38.57	331	43.50	56.50	33.33	47.20
11/17/77	610	92.13	7.87	434	68.20	31.80	432	62.50	37.50	41.67	29.75
01/12/78	520	95.19	4.81	213	34.74	65.26	358	5.59	94.41	51.67	69.97
02/20/78	995	96.58	3.42	271	60.15	39.85	353	53.26	46.74	63.33	39.48
04/13/78	743	94.48	5.52	475	64.63	35.37	686	75.95	24.05	48.33	44.00
06/15/78	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	20.00	1.17
02/22/79	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0.00	0.00

¹The % of infested leaves does not include leaves where only adults were found.

% Infested Leaves = $\frac{\text{No leaves with live forms}}{\text{No of sampled leaves}}$

²Infestation Index = $\frac{(\text{Eggs} + \text{N I} + \text{N II} + \text{N III} + \text{Pupae})}{\text{No of sampled leaves}}$ = $\frac{\text{live forms}}{60}$

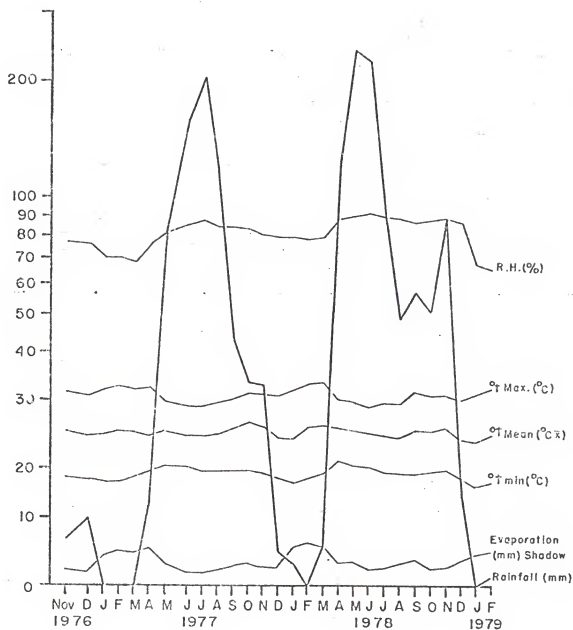


Figure 9. Average monthly temperature, relative humidity, rainfall, and evaporation (shadow) for Santa Lucia and Apoliro Citrus Orchards.

TABLE 2

SUMMARY OF MONTHLY DATA RELATING TO TEMPERATURE, RELATIVE HUMIDITY, RAINFALL
AND EVAPORATION FOR "APOLIRO" AND "SANTA LUCIA" ORCHARDS*

	Nov. 76	Dec. 76	Jan. 77	Feb. 77	Mar. 77	Apr. 77	May 77	Jun. 77	Jul. 77
Rainfall (m.m.) (Precipitation)	6.3	9.9	0.0	0.0	0.0	12.2	81.0	157.7	205.5
Mean Maximum Temperature - °C	31.4	30.7	31.9	32.7	32.1	32.3	29.9	29.0	29.0
Mean Minimum Temperature - °C	18.0	17.5	16.9	17.0	18.0	19.4	20.2	20.2	19.3
Mean Temperature - °C	24.9	24.2	24.4	24.9	24.8	24.4	25.0	24.4	24.3
Mean Relative Humidity Daily (%)	77	76	70	70	68	76	81	85	87
Mean Evaporation Daily (m.m.)(shadow)	1.9	1.6	3.9	4.4	4.2	4.9	2.7	1.6	1.6

*Data available from Agro-Meteorological Station, C.A. Central "Rio Turbio"

TABLE 2--Extended

	Aug. 77	Sep. 77	Oct. 77	Nov. 77	Jan. 78	Feb. 78	Apr. 78	Jun. 78	Feb. 79
Rainfall (m.m.) (Precipitation)	111.2	43.0	33.5	32.9	2.8	0.0	121.0	225.0	1.0
Temperature - °C	Mean Maximum	30.1	31.2	31.1	31.8	33.1	30.0	28.7	32.0
	Mean Minimum	19.5	19.6	19.0	16.7	17.6	20.8	20.2	16.7
	Mean	24.5	26.3	25.6	23.8	25.4	25.4	24.6	24.4
Mean Relative Humidity Daily (%)	84	84	83	80	79	78	88	91	65
Mean Evaporation Daily (m.m.)(shadow)	1.9	2.4	2.7	2.2	4.9	5.5	2.7	1.9	4.3

coccinellids of the genus Delphastus which were found as larvae and adults and observed to feed on all stages of A. woglumi. Three species of Delphastus were identified: D. pusillus (Lec.), Delphastus sp. near argentinus Nunenmacher, and Delphastus sp. (Coleoptera: Coccinellidae). However, the combined effect of these observed and suspected mortality factors did not prevent a subsequent increase of the citrus blackfly populations to even higher peaks when more favorable conditions returned.

Figure 10 and Table 3 show the population trends of the citrus blackfly pupae and the number of total, healthy, dead and parasitized (with exit hole of the parasite) individuals per sample date.

Figure 11 and Table 4 show the percentage of parasitism in dissected live forms (nymphs III and pupae) of citrus blackfly per sample. These live forms were third nymphal instars and pupae counted as "healthy" and dissected in order to more accurately measure the percent parasitism of the field population. Dissections were made from February 1977 to the end of the study.

From the data it is evident that prior to release of the parasite, P. opulenta, the citrus blackfly was subject to high levels of unexplained mortality. For example, on January 13, 1977, only 9.71% of the pupae were alive, and by January 27, this had declined to 3.39% with 42.37% of the pupae showing emergence holes of Cales sp. (Hymenoptera: Aphelinidae). Still later on March 10, 1977, 25.71% of the pupae were found by dissection to be parasitized by Cales sp. However, the effects of this mortality failed to prevent resurgence of the citrus blackfly to the even higher level observed June 16, immediately before P. opulenta increased sufficiently to have a measurable effect on the host population.

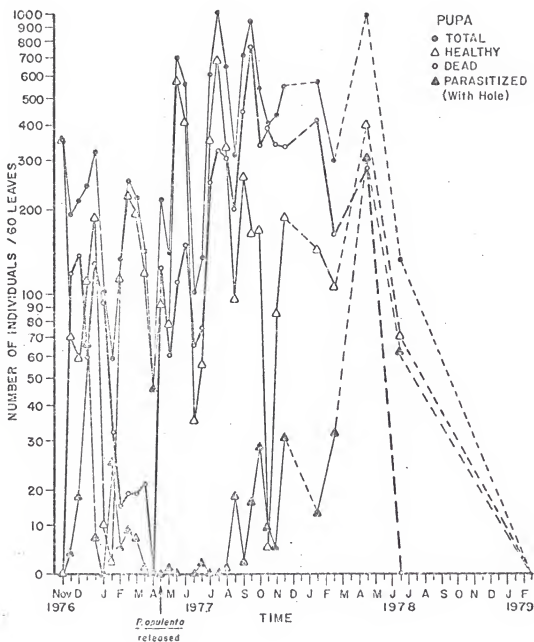


Figure 10. Total, healthy, dead, and parasitized pupa populations of *A. woglumi* observed on leaves of *C. sinensis* var. "California" at Hacienda Santa Lucia, Yaritagua. (For an explanation of dashed line, see page 38.)

TABLE 3

EGGS, PUPAE AND ADULTS OF *A. WOGLUMI* ON 60 SAMPLED LEAVES PER DATE
 LOCALITY: YARITAGUA (HACIENDA "SANTA LUCIA")

Date	Eggs	Pupae			Adults	% Infested Leaves ¹	Infestation Index ²
		Total	% Healthy	% Dead			
11/11/76	3741	355	100.00	0.00	3	48.33	90.55
11/18/76	1365	193	36.79	61.14	2	28.33	32.27
12/02/76	813	215	27.44	64.19	44	26.67	15.25
12/16/76	1639	240	46.67	25.00	245	33.33	29.93
12/30/76	2079	325	58.15	39.69	53	35.00	42.95
01/13/77	530	103	9.71	90.29	59	26.67	10.27
01/27/77	876	59	3.39	54.24	1	23.33	21.33
02/11/77	388	133	84.96	11.28	0	25.00	15.70
02/25/77	346	256	89.06	7.42	139	33.33	17.70
03/10/77	2691	221	88.24	8.60	70	40.00	54.55
03/24/77	2364	142	84.51	14.79	125	35.00	54.33
04/11/77	2272	46	100.00	0.00	103	40.00	69.17
04/21/77	683	217	43.32	56.68	17	45.00	47.42
05/05/77	838	139	56.12	43.17	13	51.67	50.48
05/19/77	1294	695	84.17	15.83	156	48.33	43.20
06/02/77	5721	562	73.31	26.69	423	63.33	116.32
06/16/77	5389	100	35.00	65.00	252	68.33	125.18
06/30/77	2203	134	41.79	56.72	92	75.00	98.53

TABLE 3--Continued

Date	Eggs	Pupae				Adults	% Infested Leaves ¹	Infestation Index ²
		Total	% Healthy	% Dead	% Parasitized (with holes)			
07/14/77	1335	606	58.42	41.58	0.00	56	58.33	80.85
07/28/77	2551	1019	68.20	31.80	0.00	304	63.33	72.95
08/11/77	6169	647	52.40	47.45	0.15	310	53.33	125.23
08/25/77	4176	315	30.48	63.81	5.71	36	60.00	112.08
09/08/77	1522	712	37.22	62.50	0.28	3	61.67	61.43
09/22/77	1233	940	17.45	80.85	1.70	55	56.67	52.97
10/06/77	1503	536	31.53	63.06	5.41	113	41.67	34.92
10/20/77	2579	404	1.24	96.29	2.48	43	38.33	56.12
11/03/77	1416	429	19.81	79.02	1.17	21	33.33	47.20
11/17/77	469	553	34.00	60.40	5.61	0	41.67	29.75
01/12/78	3464	573	25.31	72.43	2.27	125	51.67	69.97
02/20/78	952	299	35.12	54.18	10.70	26	63.33	39.48
04/13/78	707	985	40.91	28.22	30.86	27	48.33	44.00
06/15/78	0	132	53.03	0.00	46.97	0	20.00	1.17
02/22/79	0	0	0.00	0.00	0.00	0	0.00	0.00

¹The % of infested leaves does not include leaves where only adults were found.

% Infested Leaves = $\frac{\text{No leaves with live forms}}{60}$

²Infestation Index = $\frac{(\text{Eggs} + \text{NI} + \text{NII} + \text{NIII} + \text{Pupae})}{\text{No of sampled leaves}} = \frac{\text{live forms}}{60}$

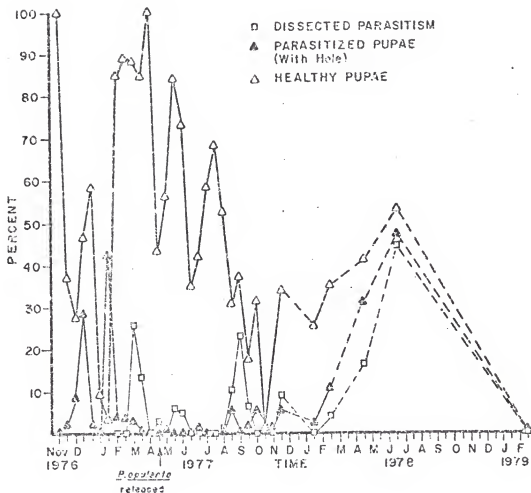


Figure 11. Percent healthy and parasitized (with hole) pupae and percent dissected parasitism of *A. woglumi* observed on leaves of *C. sinensis* var. "California" at Hacienda Santa Lucia, Yaritagua. (For an explanation of dashed line, see page 38.)

TABLE 4

PERCENT PARASITISM OF DISSECTED LIVE FORMS OF *A. WOGLUMI* ON 60 LEAVES PER SAMPLE
 LOCALITY: YARITAGUA (HACIENDA "SANTA LUCIA")

Date	% Infested Leaves ¹	Infestation Index ²	Dissected N III Pupa	Parasitism		% of Parasites		Adult Observed Field	
				% Parasitism	% Healthy	Cales sp.	P. opulenta	Cales sp.	P. opulenta
02/11/77	25.00	15.70	3	0.00	100.00	0.00	0.00	0	0
02/25/77	33.33	17.70	0	0.00	100.00	0.00	0.00	0	0
03/10/77	40.00	54.55	12	25.71	74.29	25.71	0.00	0	0
03/24/77	35.00	54.33	3	13.27	86.73	13.27	0.00	0	0
04/11/77	40.00	69.17	17	0.00	100.00	0.00	0.00	0	0
04/21/77	45.00	47.42	30	3.00	97.00	3.00	0.00	0	0
05/05/77	51.67	50.48	61	0.00	100.00	0.00	0.00	0	0
05/19/77	48.33	43.20	0	6.00	94.00	6.00	0.00	3	0
06/02/77	53.33	116.32	0	4.95	95.05	4.95	0.00	1	0
06/16/77	58.33	125.18	69	0.00	100.00	0.00	0.00	2	0
06/30/77	75.00	98.53	43	0.00	100.00	0.00	0.00	0	0
07/14/77	58.33	80.85	12	0.00	100.00	0.00	0.00	0	0
07/23/77	63.33	72.95	5	0.00	100.00	0.00	0.00	0	0
08/11/77	53.33	125.23	21	1.00	99.00	1.00	0.00	0	0
08/25/77	60.00	112.03	20	10.29	89.71	10.29	0.00	0	0
09/08/77	61.67	61.43	10	23.00	77.00	21.00	2.00	0	0
09/22/77	55.67	52.97	37	6.36	93.64	6.36	0.00	0	0

release date 04/22/77

TABLE 4--Continued

Date	% Infested Leaves ¹	Infestation Index ²	Dissected		Parasitism		% of Parasites		Adult Observed Field	
			N	III Pupa	% Parasitism	% Healthy	Cales sp.	P. opulenta	Cales sp.	P. opulenta
10/06/77	41.67	34.92	0	100	0.00	100.00	0.00	0.00	0	0
10/20/77	38.33	56.12	55	5	3.33	96.67	3.33	0.00	0	0
11/03/77	33.33	47.20	32	85	0.00	100.00	0.00	0.00	0	0
11/17/77	41.67	29.75	57	43	9.00	91.00	9.00	0.00	1	0
01/12/78	51.67	69.97	6	94	0.00	100.00	0.00	0.00	0	1
02/20/78	63.33	39.48	15	85	4.00	96.00	4.00	0.00	2	4
04/13/78	48.33	44.00	0	100	16.00	84.00	7.00	9.00	1	0
05/15/78	20.00	1.17	0	70	44.29	55.71	0.00	44.29	0	5
02/22/79	0.00	0.00	0	0	0.00	0.00	0.00	0.00	0	0

¹The % of infested leaves does not include leaves where only adults were found.

% Infested Leaves = $\frac{\text{N}^\circ \text{ Leaves with live forms}}{60}$

²Infestation Index = $\frac{(\text{Eggs} + \text{NI} + \text{NII} + \text{NIII} + \text{Pupae}) \times \text{live forms}}{\text{N}^\circ \text{ of sampled leaves}} = \frac{\quad}{60}$

There is also a significant change in the relation of mortality of immature stages of the citrus blackfly and total population numbers following the release of 200 P. opulenta on 2 different trees (Fig. 3, inoculated trees) of this grove. Prior to release there was no correlation between number of dead individuals and total numbers of the populations sampled. Following release of P. opulenta there was an abrupt shift to a direct relation between the number of dead individuals and the total number present resulting in coinciding peaks for the 2 categories (Figs. 6, 7, 8, and 10).

The first detection of the released parasite was made on September 8, 1977, when 2% of the citrus blackflies included in the samples were parasitized by P. opulenta. The first adult parasite was seen in the field on January 12, 1978 (Table 4). However, parasitized pupae (with exit hole of the parasite) started to increase after August 1977, and peaked in April 1978 (Table 3). Parasitism as found by dissection varied but was generally low until February 1978, when it started to increase and reached a peak on June 1978, with 44.29%. At this time, P. opulenta was found to have almost completely displaced the only native parasite (Cales sp.) present in earlier samples. On this date, the parasitized pupae (with exit hole of the parasite) reached the highest percentage (Table 3 and Fig. 11), and all other stages of citrus blackfly declined to 0.

In February 1979, complete biological control had been achieved, and by December 1979, it was impossible to find any sign of A. woglumi in this citrus grove.

Other natural enemies observed as mortality factors were yellow aschersonia (Aschersonia goldiana Sacc. and Ellis); the jumping spiders

(Attidae); the coccinellid predators Azya sp., Scymnus sp. and Cycloneda sanguinea L.; an anthocorid predator (Hemiptera: Anthrocoridae); the assassin bug (Zelus sp.) and the tettigoniid predator Phlugis teres DeGeer.

Apoliro Experimental Orchard

This citrus grove contained 2,635 trees in an area of 119,280 m² (Fig. 12), and all trees received the last pesticide treatment (1 l. Endrin + 3 kg. foliar fertilizer/400 ls. water) on November 10, 1976, but 2 of the sample trees did not receive this application. All pesticide treatments were suspended from this date. This farm was managed as a commercial grove with a good irrigation system, periodic application (prior to November 10, 1976) of insecticides and fertilizer.

Figures 13 and 14 show the population trends of citrus blackflies at Apoliro citrus grove. Figure 13 shows clearly the 5 generations of A. woglumi through the year of study from November 1976 to November 1977. Those generations were the first in November, the second in February, the third at the end of April and early May, the fourth in July, and the fifth in October. Figure 14 shows the peaks of each of the nymphal instars and the shift from 1 nymphal stage to the next and occurred regularly every other sample date.

Figures 15, 16, and 17 show the population trends of each nymphal instar and the number of total, healthy and dead individuals for each sample date. As is evident from the data preceding release of P. opulenta on April 22, 1977, the mortality factors (biotic and abiotic) did not exert any substantial control on the populations of any stage of A. woglumi (Tables 5 and 6). However, the highest percentages of

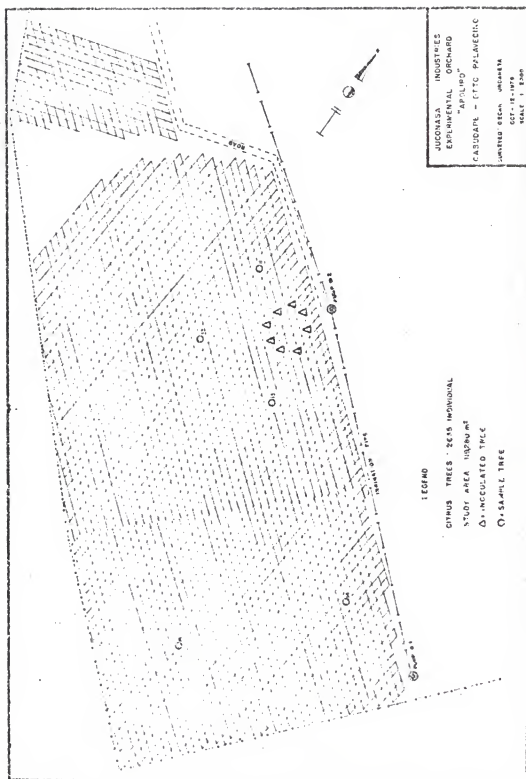


Figure 12. Apoliro Experimental Orchard, Cabudare.

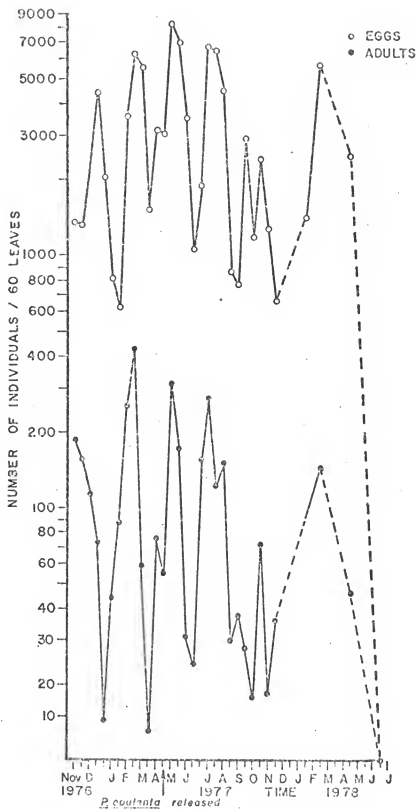


Figure 13. Egg and adult populations of *A. woglumi* observed on leaves of *C. sinensis* var. "Pineapple" at Apoliro Experimental Orchard, Cabudare. (For an explanation of dashed line, see page 38.)

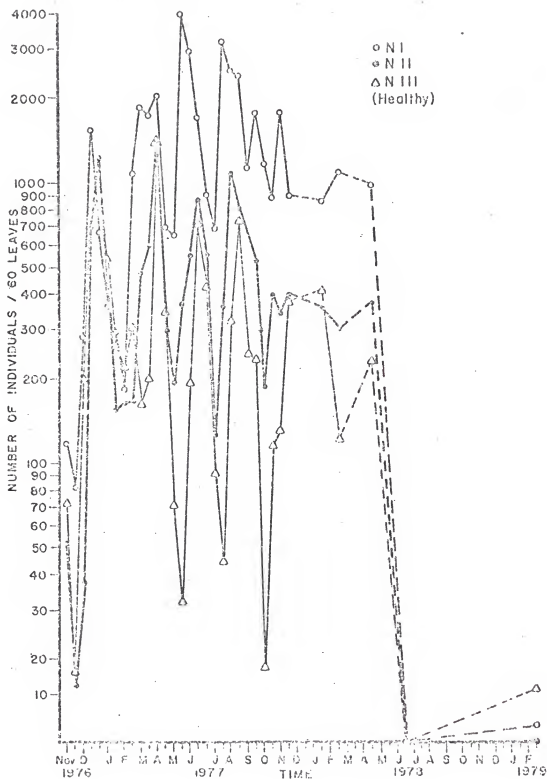


Figure 14. First, second, and third nymphal instars of *A. woglumi* observed on leaves of *C. sinensis* var. "Pineapple" at Apoliro Experimental Orchard, Cabudare. (For an explanation of dashed line, see page 38.)

Figure 15. Total, healthy, and dead first nymphal instar populations of A. woglumi observed on leaves of C. sinensis var. "Pineapple" at Apoliro Experimental Orchard, Cabudare.
(For an explanation of dashed line, see page 38.)

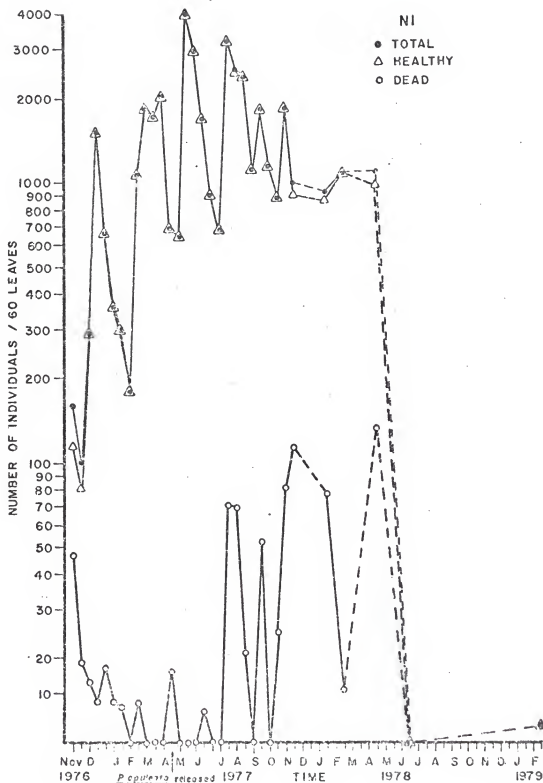
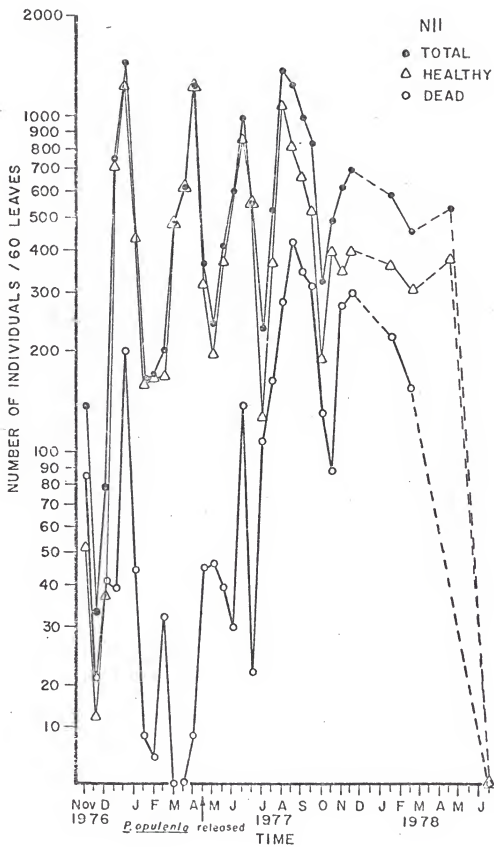


Figure 16. Total, healthy, and dead second nymphal instar populations of A. woglumi observed on leaves of C. sinensis var. "Pineapple" at Apoliro Experimental Orchard, Cabudare. (For an explanation of dashed line, see page 38.)



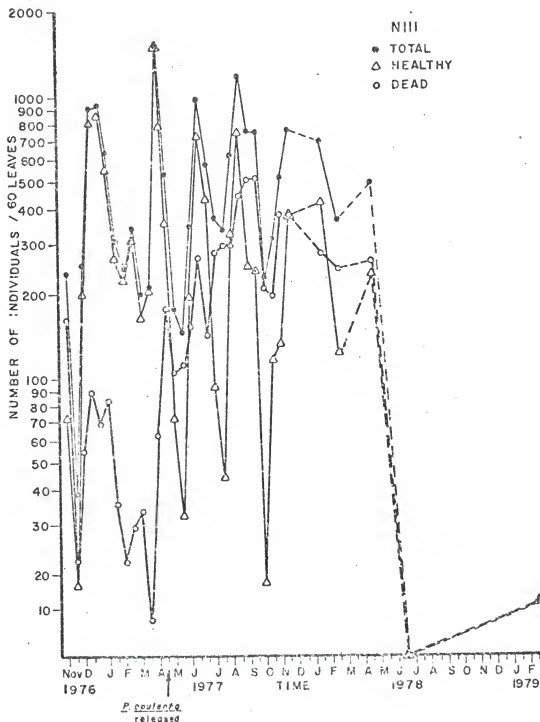


Figure 17. Total, healthy, and dead third nymphal instar populations of *A. woglumi* observed on leaves of *C. sinensis* var. "Pineapple" at Apoliro Experimental Orchard, Cabudare. (For an explanation of dashed line, see page 38.)

TABLE 5

PERCENT HEALTHY AND DEAD NYMPHS OF *A. WOGLUMI* ON 60 SAMPLED LEAVES PER DATE
 LOCALITY: CABUDARE ("APÓLIO" EXPERIMENTAL ORCHARD)

Date	Nymph I			Nymph II			Nymph III			% Infested Leaves ¹	Infestation Index ²
	Total	% Healthy	% Dead	Total	% Healthy	% Dead	Total	% Healthy	% Dead		
11/11/76	165	71.52	28.48	137	37.96	62.04	233	30.90	69.10	40.00	30.90
11/13/76	101	81.19	18.81	33	36.36	63.64	38	42.11	57.89	43.33	29.22
12/02/76	298	55.64	4.36	78	47.44	52.56	252	78.57	21.43	45.00	51.15
12/16/76	1574	99.49	0.51	754	94.83	5.17	900	90.22	9.78	58.33	129.42
12/30/76	694	97.55	2.45	1453	86.17	13.83	926	92.66	7.34	53.33	88.60
01/13/77	377	97.83	2.12	481	50.85	9.15	633	87.05	12.95	45.00	43.73
01/27/77	303	97.59	2.31	165	95.15	4.85	301	88.37	11.63	50.00	36.88
02/11/77	194	100.00	0.00	170	97.65	2.35	243	90.95	9.05	60.00	84.10
02/25/77	1097	99.27	0.73	200	84.00	16.00	339	91.45	8.55	78.33	150.67
03/10/77	1879	100.00	0.00	481	100.00	0.00	196	83.16	16.84	75.00	141.08
03/24/77	1770	100.00	0.00	606	100.00	0.00	208	96.63	3.37	71.67	72.03
04/11/77	2045	100.00	0.00	1258	99.36	0.64	1502	95.87	4.13	73.33	143.32
04/21/77	716	97.77	2.23	365	87.67	12.33	526	66.92	33.08	85.00	88.08
05/05/77	654	100.00	0.00	242	80.99	19.01	173	41.04	58.96	81.67	172.95
05/19/77	4036	100.00	0.00	411	90.51	9.49	143	22.38	77.62	91.67	194.43
05/02/77	2959	100.00	0.00	584	94.86	5.14	345	56.23	43.77	71.67	121.38
05/16/77	1732	93.65	0.35	1000	86.70	13.30	984	73.17	26.83	66.67	79.32
06/30/77	913	100.00	0.00	578	96.19	3.81	572	75.52	24.48	70.00	79.15

release date 04/22/77

TABLE 5--Continued

Date	Nymph I			Nymph II			Nymph III			% Infested Leaves ¹	Infestation Index ²
	Total	% Healthy	% Dead	Total	% Healthy	% Dead	Total	% Healthy	% Dead		
07/14/77	695	100.00	0.00	234	58.85	46.15	368	25.00	75.00	85.00	131.08
07/26/77	3298	97.85	2.15	528	69.13	30.87	336	13.10	86.90	80.00	172.33
08/11/77	2590	97.30	2.70	1378	79.68	20.32	615	52.20	47.80	83.33	142.20
08/25/77	2440	99.14	0.86	1246	65.81	34.19	1181	62.91	37.09	73.33	85.80
09/08/77	1130	100.00	0.00	1005	65.97	34.03	751	33.02	66.98	71.67	56.07
09/22/77	1858	97.15	2.85	837	62.96	37.04	745	31.95	68.05	85.00	94.33
10/06/77	1160	100.00	0.00	319	58.93	41.07	223	7.62	92.38	78.33	54.55
10/20/77	917	97.27	2.73	485	82.06	17.94	309	37.54	62.46	78.33	67.73
11/03/77	1880	95.64	4.36	617	55.75	44.25	510	25.69	74.31	81.67	61.55
11/17/77	1018	88.61	11.39	699	57.37	42.63	756	50.00	50.00	60.00	42.68
01/12/78	944	91.74	8.26	580	62.24	37.76	688	60.32	39.68	68.33	60.83
02/20/78	1104	99.00	1.00	454	66.30	33.70	361	33.52	66.48	90.00	126.20
04/13/78	1118	88.01	11.99	536	69.96	30.04	487	47.43	52.57	70.00	74.58
06/15/78	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	16.67	0.90
02/22/79	3	100.00	0.00	0	0.00	0.00	11	100.00	0.00	21.67	0.30

¹The % of infested leaves does not include leaves where only adults were found.

% Infested Leaves = $\frac{\text{No leaves with live forms}}{60}$

²Infestation Index = $\frac{(\text{Eggs} + \text{NI} + \text{NII} + \text{NIII} + \text{Pupae})}{\text{No of sampled leaves}} = \frac{\text{live forms}}{60}$

TABLE 6

EGGS, PUPAE AND ADULTS OF *A. WOGLUMI* ON 60 SAMPLED LEAVES PER DATE
LOCALITY: CABUDARE ("APOLIRO" EXPERIMENTAL ORCHARD)

Date	Eggs	Pupae				Adults	% Infested Leaves ¹	Infestation Index ²
		Total	% Healthy	% Dead	% Parasitized (with holes)			
11/11/76	1370	385	62.86	30.91	6.23	185	40.00	30.90
11/18/76	1339	609	49.92	48.11	1.97	155	43.33	29.22
12/02/76	2520	113	25.66	72.57	1.77	114	45.00	51.15
12/16/76	4469	320	63.44	30.94	5.62	74	58.33	129.42
12/30/76	2055	576	82.29	14.41	3.30	9	53.33	88.60
01/13/77	811	571	79.86	19.61	0.53	44	45.00	43.73
01/27/77	633	1016	84.74	15.26	0.00	89	50.00	36.88
02/11/77	3573	1040	86.73	12.12	1.15	255	60.00	84.10
02/25/77	6273	1292	92.88	6.04	1.08	427	78.33	150.67
03/10/77	5570	391	95.14	4.86	0.00	59	75.00	141.08
03/24/77	1521	241	94.19	3.73	2.08	6	71.67	72.08
04/11/77	3142	948	76.16	23.63	0.21	76	73.33	143.32
04/21/77	3055	1077	79.67	19.96	0.37	55	85.00	88.08
05/05/77	8291	1421	81.98	17.87	0.15	311	81.67	172.95
05/19/77	6967	394	53.05	46.70	0.25	172	91.67	194.43
06/02/77	3499	325	23.69	74.46	1.85	31	71.67	121.38
06/16/77	1058	707	54.88	44.84	0.28	24	66.67	79.32
06/30/77	1907	1293	72.78	27.07	0.15	156	70.00	79.15

TABLE 6--Continued

Date	Eggs	Pupae				Adults	% Infested Leaves ¹	Infestation Index ²
		Total	% Healthy	% Dead	% Parasitized (with holes)			
07/14/77	6718	641	38.07	61.15	0.78	273	85.00	131.08
07/28/77	6410	716	38.63	60.84	0.53	123	80.00	172.33
08/11/77	4501	580	15.86	82.93	1.21	151	83.33	142.20
08/25/77	870	1105	26.79	73.03	0.18	30	73.33	85.80
09/08/77	774	1243	44.17	55.83	0.00	38	71.67	56.07
09/22/77	2914	993	17.72	82.18	0.10	28	85.00	94.33
10/06/77	1183	1146	63.26	36.21	0.53	16	78.33	54.55
10/20/77	2417	711	33.90	66.10	0.00	72	78.33	67.73
11/03/77	1278	674	21.07	78.49	0.44	17	81.67	61.55
11/17/77	663	519	41.81	55.68	2.51	36	60.00	42.68
01/12/78	1416	936	63.25	36.54	0.21	92	68.33	60.83
02/20/78	5707	643	54.43	44.32	1.25	146	90.00	126.20
04/13/78	583	1088	36.95	50.18	12.87	46	70.00	74.58
06/15/78	0	263	20.53	0.00	79.47	0	16.67	0.90
02/22/79	0	103	3.88	58.25	37.86	0	21.67	0.30

¹The % of infested leaves does not include leaves where only adults were found.

% Infested Leaves = $\frac{\text{N}^{\circ} \text{ leaves with live forms}}{60}$

²Infestation Index = $\frac{(\text{Eggs} + \text{NI} + \text{NII} + \text{NIII} + \text{Pupae})}{\text{N}^{\circ} \text{ of sampled leaves}} = \frac{\text{live forms}}{60}$

dead first, second and third nymphal instars were in November 1976, as a consequence of the insecticide treatment (Table 5). This could also be the reason for the high percentage of dead pupae found on December 2, 1976 (Table 6). During this time, precipitation was low (Fig. 9 and Table 2); however, relative humidity was comparatively high (76%) and the leaves were regularly covered by morning dew which favored the development of Aegerita webberi, the only fungus pathogen present in this grove during the study. Other natural enemies found in highest number during November and December were Scymnus sp., Delphastus spp., Nodita sp., and Mantispidia sp. The combined effects of these observed and suspected mortality factors did not prevent the citrus blackfly populations from increasing to higher levels.

Figure 18 and Table 6 show the population trends of the citrus blackfly pupae and the number of total, healthy, dead, and parasitized (with exit hole of the parasite) individuals per each sample date.

Figure 19 and Table 7 show the percentage of parasitism in dissected "healthy" live forms (nymphs III and pupae) of citrus blackfly per sample.

From the data it is evident that prior to release of the parasite, P. opulenta, the citrus blackfly, though subject to high levels of unexplained mortality, was able to maintain a population able to erupt at frequent intervals to very high levels.

Following release of 100 P. opulenta on each of 8 different trees (Fig. 12, inoculated trees), the number of dead citrus blackfly increased and peaked at times coinciding with the peaks of immature instars of A. woglumi (Figs. 15, 16, 17, and 18). It should also be noted that percentages of dead citrus blackflies increased as

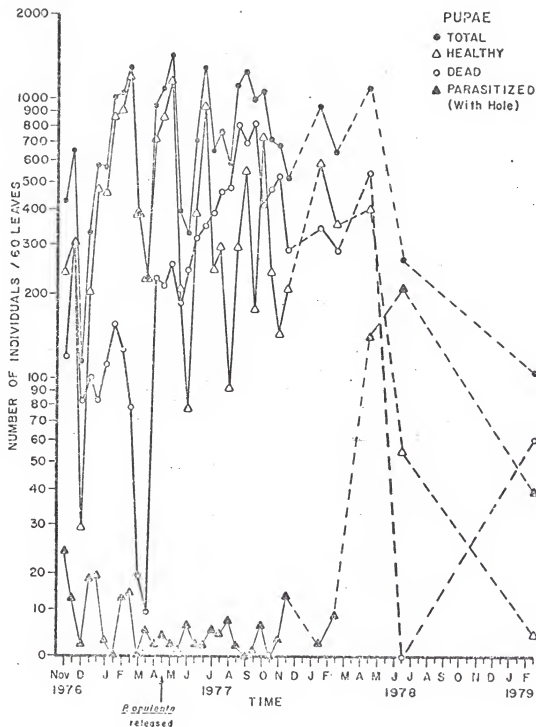


Figure 18. Total, healthy, dead, and parasitized pupa populations of *A. woglumi* observed on leaves of *C. sinensis* var. "Pineapple" at Apoliro Experimental Orchard, Cabudare. (For an explanation of dashed line, see page 38.)

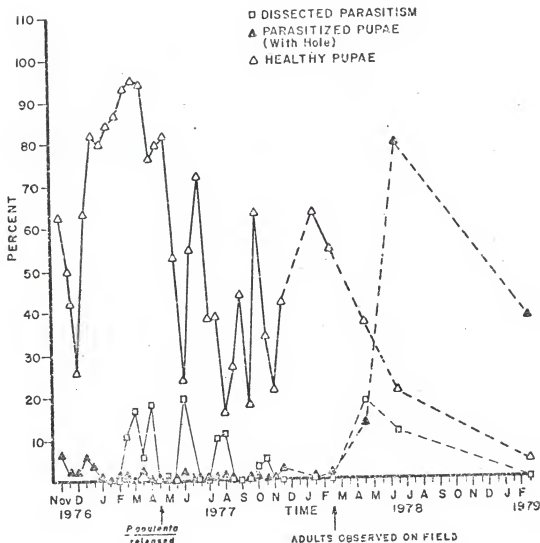


Figure 19. Percent healthy and parasitized (with hole) pupae and percent dissected parasitism of *A. woglumi* observed on leaves of *C. sinensis* var. "Pineapple" at Apoliro Experimental Orchard, Cabudare. (For an explanation of dashed line, see page 38.)

TABLE 7

PERCENT PARASITISM OF DISSECTED LIVE FORMS OF *A. WOGLUMI* ON 60 LEAVES PER SAMPLE
LOCALITY: CABUDARE ("APOLIRO" EXPERIMENTAL ORCHARD)

Date	% Infested Leaves ¹	Infestation Index ²	Dissected		Parasitism		% of Parasites		Adults Observed Field	
			N	III Pupa	% Parasitism	% Healthy	Cales sp.	<i>P. opulenta</i>	Cales sp.	<i>P. opulenta</i>
02/11/77	60.00	84.10	--	95	0.00	100.00	0.00	0.00	0	0
02/25/77	78.33	150.67	--	85	10.59	89.41	10.59	0.00	0	0
03/10/77	75.00	141.00	16	80	16.67	83.33	16.67	0.00	0	0
03/24/77	71.67	72.08	19	94	5.31	94.69	5.31	0.00	2	0
04/11/77	73.33	143.32	5	95	18.00	82.00	18.00	0.00	2	0
04/21/77	85.00	88.08	1	99	0.00	100.00	0.00	0.00	2	0
05/05/77	81.67	172.95	--	100	1.00	99.00	1.00	0.00	2	0
05/19/77	91.67	194.43	--	100	0.00	100.00	0.00	0.00	3	0
05/02/77	71.67	121.38	--	57	19.30	80.70	19.30	0.00	4	0
06/16/77	66.67	79.32	--	100	10.00	90.00	10.00	0.00	2	0
06/30/77	70.00	79.15	5	95	0.00	100.00	0.00	0.00	2	0
07/14/77	85.00	131.08	2	98	0.00	100.00	0.00	0.00	2	0
07/28/77	80.00	172.33	--	100	10.00	90.00	10.00	0.00	1	0
08/11/77	83.33	142.20	34	66	11.00	89.00	11.00	0.00	0	0
03/25/77	73.33	85.80	5	95	0.00	100.00	0.00	0.00	1	0
09/08/77	71.67	56.07	7	93	0.00	100.00	0.00	0.00	0	0
09/22/77	85.00	94.33	44	56	0.00	100.00	0.00	0.00	0	0
10/06/77	78.33	54.55	--	103	3.00	97.00	3.00	0.00	1	0

release date 04/22/77

TABLE 7--Continued

Date	% Infested Leaves ¹	Infestation Index ²	Dissected		Parasitism		% of Parasites		Adults Observed Field	
			N	III Pupa	% Parasitism	% Healthy	Cales sp.	P. opulenta	Cales sp.	P. opulenta
10/20/77	78.33	67.73	29	67	5.00	95.00	5.00	0.00	0	0
11/03/77	81.67	61.55	15	93	0.00	100.00	0.00	0.00	3	0
11/17/77	60.00	42.68	--	100	0.00	100.00	0.00	0.00	2	0
01/12/78	68.33	60.83	36	64	0.00	100.00	0.00	0.00	6	0
02/20/78	90.00	126.20	--	100	0.00	100.00	0.00	0.00	12	8
04/13/78	70.00	74.58	3	89	18.48	81.52	7.61	10.87	6	5
05/15/78	16.67	0.90	--	54	11.11	88.89	0.00	11.11	2	11
02/22/79	21.67	0.30	11	4	0.00	100.00	0.00	0.00	4	2

¹The % of infested leaves does not include leaves where only adults were found.

% Infested Leaves = $\frac{\text{N}^{\circ} \text{ leaves with live forms}}{60}$

²Infestation Index = $\frac{(\text{Eggs} + \text{NI} + \text{NII} + \text{NIII} + \text{Pupae}) \cdot \text{live forms}}{\text{N}^{\circ} \text{ of sampled leaves} \cdot 60}$

P. opulenta increased sufficiently to have a measurable effect on the host populations (Tables 5 and 6).

Although adult parasites were first seen in the field on February 20, 1978, the first evidence of presence of P. opulenta in the leaf samples was observed on April 13, 1978, when 10.87% of the citrus blackfly pupae were parasitized by P. opulenta (Table 7). Parasitized pupae (with exit hole of the parasite) increased steadily and peaked in June 1978 with 79.47% when P. opulenta was found to have almost completely displaced the only native parasite (Cales sp.) (Tables 6 and 7). On this date, June 1978, all other stages of citrus blackfly declined to 0.

By February 1979, only 3 first nymphal instars, 11 third nymphal instars and 4 pupae were found and complete biological control had been achieved.

Other natural enemies observed as mortality factors were the coccinellid predator Cycloneda sanguinea; the assassin bug (Zelus sp.) and a spider web in which 34 adult citrus blackflies were observed to be trapped.

Gloria de Lara Citrus Orchard

This citrus grove contained 2,045 trees in an area of 78,800 m² (Fig. 20) and was supposed to receive normal commercial management. However, because of management changes by the owner and uncertainties caused by the agricultural reform of the government, there was a shortage of workers and a succession of administrators responsible for the grove. As a result, cultural practices including irrigation, fertilization and application of pesticides were neglected or applied

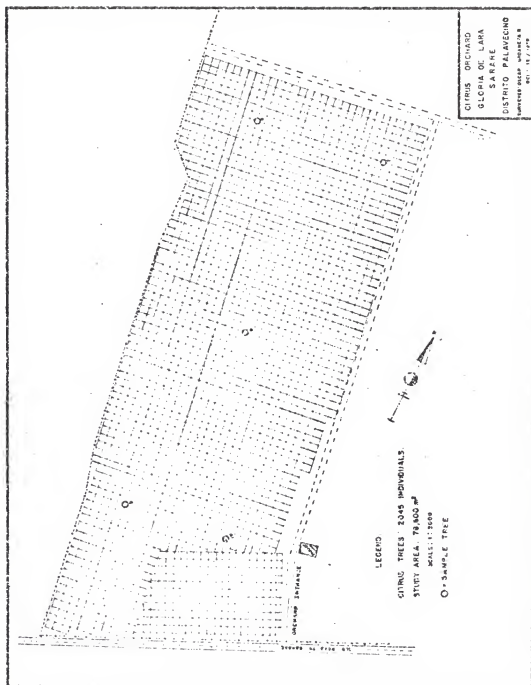


Figure 20. Gloria de Lara, Sarare.

capriciously. The parasite, P. opulenta, was not released in this citrus grove.

Figures 21 and 22 show trend of citrus blackfly populations at Glorida de Lara citrus grove. Figure 21 clearly shows 5 generations of A. woglumi during the year of study from November 1976 to November 1977. Those generations were the first in December, the second at the end of February and early March, the third in June, the fourth in August, and the fifth in October which was present only in the egg stage probably because of high pupal mortality caused by fungus diseases (A. webberi, A. aleyrodis, and A. goldiana) during the period from August 25, 1977, to November 3, 1977 (Table 8), when the pupae populations declined to 0. During this time, high precipitation (Table 9) favored the development of fungus diseases. Fungus diseases were the principal mortality factor on this farm throughout the study period and probably results from the generally high rainfall of this area (Table 9). However, fungi did not prevent resurgence of citrus blackfly pupae, and on February 20, 1978, the percentage of healthy pupae was 67.33% (Table 8). Figure 22 shows the peaks of each of the nymphal instars and the shift from 1 nymphal instar to the next.

Figures 23, 24, and 25 show the population trends of each nymphal instar and the number of total, healthy and dead individuals for each sample date. Table 10 shows the percentage of healthy and dead nymphs of A. woglumi.

Figure 26 and Table 8 show the population trend of the citrus blackfly pupae and the number of total, healthy, dead and parasitized (with exit hole of the parasite) individuals per sample date.

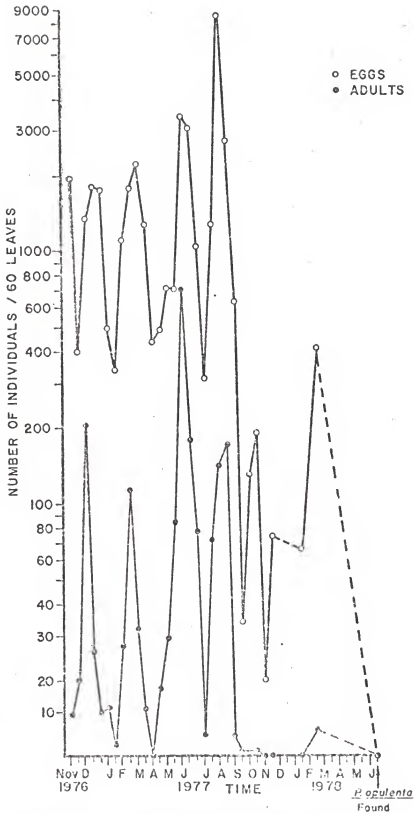


Figure 21. Egg and adult populations of *A. woglumi* observed on leaves of *C. sinensis* var. "Valencia" at Glorinda de Lara, Sarare. (For an explanation of dashed line, see page 38.)

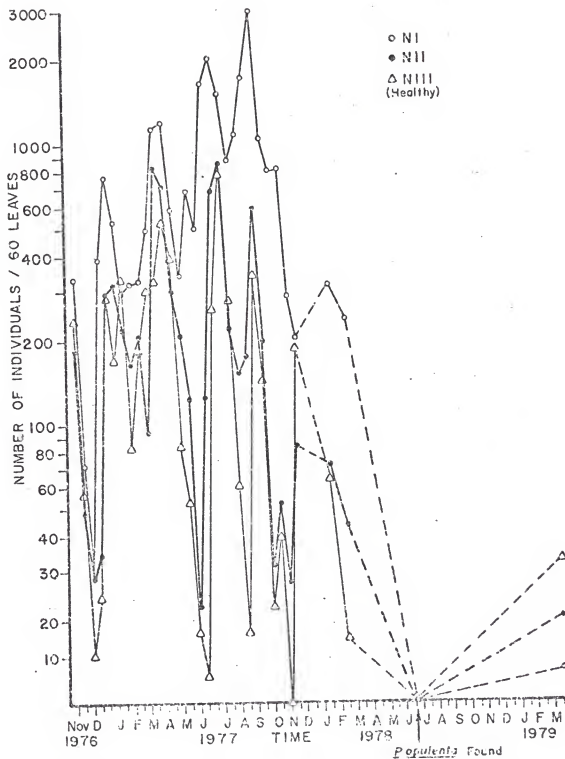


Figure 22. First, second, and third nymphal instars of *A. woglumi* observed on leaves of *C. sinensis* var. "Valencia" at Gloria de Lara, Sarare. (For an explanation of dashed line, see page 38.)

TABLE 8

EGGS, PUPAE AND ADULTS OF *A. NOGLUMI* ON 60 SAMPLED LEAVES PER DATE
 LOCALITY: SARARE ("GLORIA DE LARA" CITRUS ORCHARD)

Date	Eggs	Pupae			Adults	% Infested Leaves ¹	Infestation Index ²
		Total	% Healthy	% Dead			
11/11/76	1944	448	96.65	2.90	9	41.67	52.15
11/18/76	401	269	58.74	41.26	20	26.67	12.23
12/02/76	1347	351	33.05	66.10	206	38.33	25.50
12/16/76	1792	298	35.99	59.52	26	35.00	39.02
12/30/76	1750	97	35.05	28.87	10	51.67	52.18
01/13/77	492	649	98.92	1.08	11	40.00	35.85
01/27/77	340	378	81.22	16.40	2	38.33	24.70
02/11/77	1110	419	70.41	28.40	27	38.33	32.80
02/25/77	1783	532	67.67	32.14	113	46.67	47.60
03/10/77	2230	1001	89.41	8.19	32	46.67	66.82
03/24/77	1276	282	90.78	8.51	11	61.67	63.52
04/11/77	438	623	89.25	9.95	0	48.33	56.90
04/21/77	481	960	78.33	21.67	17	46.67	41.63
05/05/77	718	509	74.66	25.15	29	55.0	28.72
05/19/77	711	601	69.55	30.12	84	53.33	33.03
06/02/77	3400	370	47.57	52.43	701	55.00	68.48
06/16/77	3098	66	25.76	74.24	179	68.33	81.28
06/30/77	1035	230	23.91	76.09	77	65.00	67.37

TABLE 8--Continued

Date	Eggs	Pupae			Adults	% Infested Leaves ²	Infestation Index ¹
		Total	% Healthy	% Dead			
07/14/77	314	647	48.84	51.16	4	68.33	62.75
07/28/77	1268	1087	71.76	28.24	72	75.00	57.00
08/11/77	8605	1053	72.65	27.35	142	95.00	177.43
08/25/77	2718	455	7.91	92.09	170	73.33	77.82
09/08/77	634	508	1.77	98.23	4	76.67	75.47
09/22/77	34	524	26.91	73.09	1	58.33	25.82
10/06/77	129	285	28.42	71.58	1	48.33	17.78
10/20/77	190	418	1.44	97.61	1	48.33	18.27
11/03/77	20	388	0.00	100.00	0	15.00	5.52
11/17/77	74	264	6.82	92.80	0	25.00	9.37
01/12/78	66	96	13.54	86.46	0	23.33	8.73
02/20/78	413	339	66.67	33.04	5	38.33	15.48
06/15/78	0	101	67.33	0.00	0	13.33	1.13
03/27/79	0	220	0.00	67.73	0	13.33	0.97

¹The % of infested leaves does not include leaves where only adults were found.

% Infested Leaves = $\frac{\text{N}^{\circ} \text{ leaves with live forms}}{60}$

²Infestation Index = $\frac{(\text{Eggs} + \text{NI} + \text{NII} + \text{NIII} + \text{Pupae})}{\text{N}^{\circ} \text{ of sampled leaves}} = \frac{\text{live forms}}{60}$

TABLE 9
SUMMARY OF MONTHLY DATA RELATING TO RAINFALL FOR "GLORIA DE LARA" CITRUS ORCHARD*

	May 77	Jun. 77	Jul. 77	Aug. 77	Sep. 77	Oct. 77	Nov. 77	Dec. 77	Jan. 78
Rainfall (m.m.)	223.4	220.8	265.4	239.2	282.8	198.8	103.7	0.0	8.5
(Precipitation)	Feb. 78	Mar. 78	Apr. 78	May 78	Jun. 78	Jul. 78	Aug. 78	Sep. 78	Oct. 78
	0.0	6.0	245.4	316.7	289.7	314.0	165.9	142.2	158.4

*Data available from Experimental Station of Araure (Ecology Section)

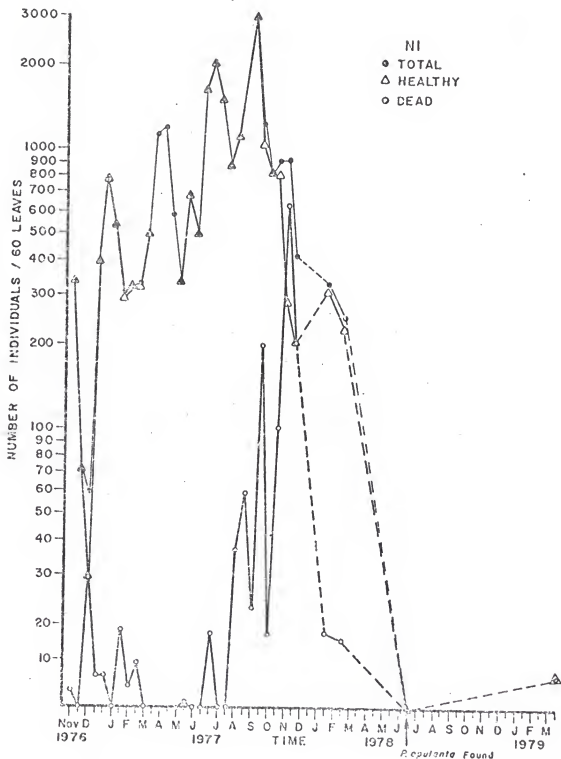


Figure 23. Total, healthy, and dead first nymphal instar populations of *A. woglumi* observed on leaves of *C. sinensis* var. "Valencia" at Gloria de Lara, Sarare. (For an explanation of dashed line, see page 38.)

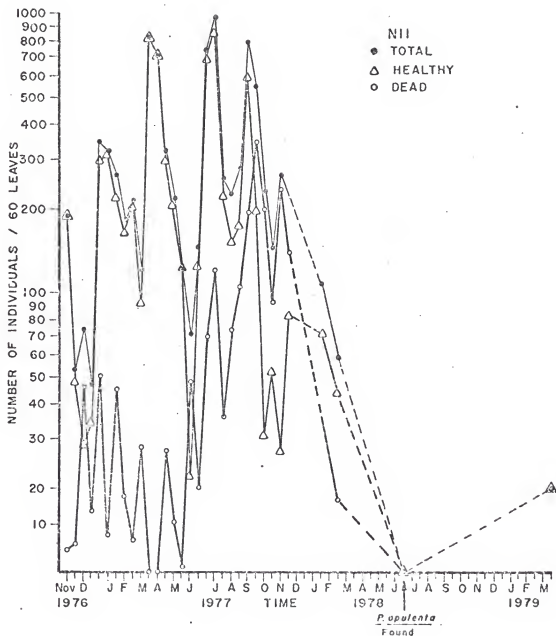


Figure 24. Total, healthy, and dead second nymphal instar populations of *A. woglumi* observed on leaves of *C. sinensis* var. "Valencia" at Glorinda de Lara, Sarare. (For an explanation of dashed line, see page 38.)

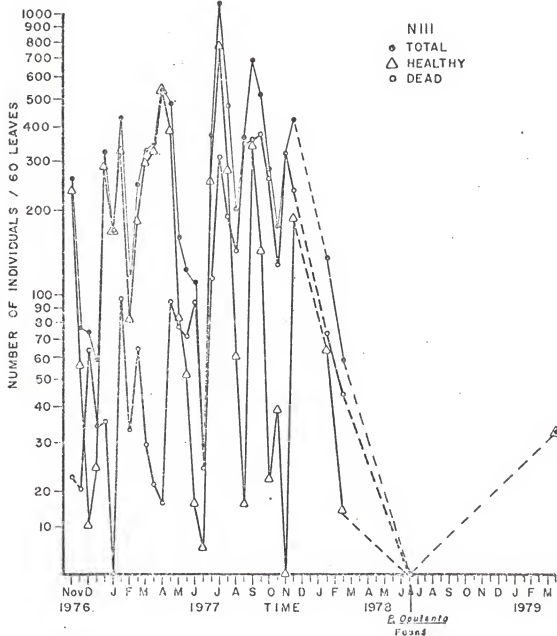


Figure 25. Total, healthy, and dead third nymphal instar populations of *A. woglumi* observed on leaves of *C. sinensis* var. "Valencia" at Glorinda de Lara, Sarare. (For an explanation of dashed line, see page 38.)

TABLE 10

PERCENT HEALTHY AND DEAD NYMPHS OF A. WOGLUMI ON 60 SAMPLED LEAVES PER DATE
LOCALITY: SARARE ("GLORIA DE LARA" CITRUS ORCHARD)

Date	Nymph I			Nymph II			Nymph III			% Infested Leaves ¹	Infestation Index ²
	Total	% Healthy	% Dead	Total	% Healthy	% Dead	Total	% Healthy	% Dead		
11/11/76	335	95.10	0.90	188	97.87	2.13	258	91.47	8.53	41.67	52.15
11/18/76	71	100.00	0.00	53	90.57	9.43	76	73.68	26.32	26.67	12.23
12/02/76	59	49.15	50.85	74	37.84	62.16	73	13.70	86.30	38.33	25.50
12/16/76	393	98.47	1.53	47	72.34	27.66	58	41.38	58.62	35.00	39.02
12/30/76	769	99.22	0.78	346	85.55	14.45	323	89.16	10.84	51.67	52.18
01/13/77	532	100.00	0.00	323	97.83	2.17	169	100.00	0.00	40.00	35.85
01/27/77	303	94.16	5.84	262	82.82	17.18	424	77.36	22.64	38.33	24.70
02/11/77	322	98.76	1.24	180	90.56	9.44	115	71.30	28.70	38.33	32.80
02/25/77	332	97.29	2.71	213	97.18	2.82	247	74.09	25.91	46.67	47.60
03/10/77	494	100.00	0.00	121	76.86	23.14	326	91.10	8.90	46.67	66.82
03/24/77	1133	100.00	0.00	823	100.00	0.00	344	93.90	6.10	61.67	63.52
04/11/77	1193	100.00	0.00	705	100.00	0.00	538	97.03	2.97	48.33	56.90
04/21/77	583	100.00	0.00	323	91.64	8.36	480	80.42	19.58	46.67	41.63
05/05/77	337	100.00	0.00	215	95.35	4.65	160	51.88	48.13	55.00	28.72
05/19/77	680	99.85	0.15	123	99.19	0.81	123	42.28	57.72	53.33	33.03
06/02/77	495	100.00	0.00	70	31.43	68.57	110	14.55	85.45	55.00	68.48
06/16/77	1632	100.00	0.00	145	86.21	13.79	29	17.24	82.76	68.33	81.28
06/30/77	2038	99.17	0.83	745	90.74	9.26	369	69.11	30.89	65.00	67.37

TABLE 10--Continued

Date	Nymph I		Nymph II		Nymph III		% Infested Leaves ¹	Infestation Index ²
	Total	% Healthy	% Dead	Total	% Healthy	% Dead		
07/14/77	1506	100.00	0.00	975	87.59	12.41	1086	62.75
07/23/77	874	100.00	0.00	256	85.94	14.06	468	57.00
08/11/77	1102	96.64	3.36	225	67.11	32.89	202	177.43
08/25/77	1785	96.69	3.31	277	62.45	37.55	360	77.82
09/03/77	2982	99.23	0.77	782	75.32	24.68	692	75.47
09/22/77	1230	83.98	16.02	545	36.15	63.85	514	25.82
10/06/77	821	97.93	2.07	229	13.54	86.46	280	17.78
10/20/77	910	83.90	11.10	144	36.11	63.89	176	18.27
11/03/77	917	30.97	69.03	261	10.34	89.66	317	5.52
11/17/77	414	48.55	51.45	222	37.39	62.61	420	9.37
01/12/78	328	94.82	5.18	107	66.36	33.64	135	8.73
02/20/78	248	93.95	6.05	59	72.88	27.12	58	15.48
06/15/78	0	0.00	0.00	0	0.00	0.00	0	1.33
03/27/79	6	100.00	0.00	20	100.00	0.00	32	0.97

¹The % of infested leaves does not include leaves where only adults were found.

% Infested Leaves = $\frac{\text{N}^{\circ} \text{ leaves with live forms}}{60}$

²Infestation Index = $\frac{(\text{Eggs} + \text{NI} + \text{NII} + \text{NIII} + \text{Pupae}) \times \text{live forms}}{\text{N}^{\circ} \text{ of sampled leaves} \times 60}$

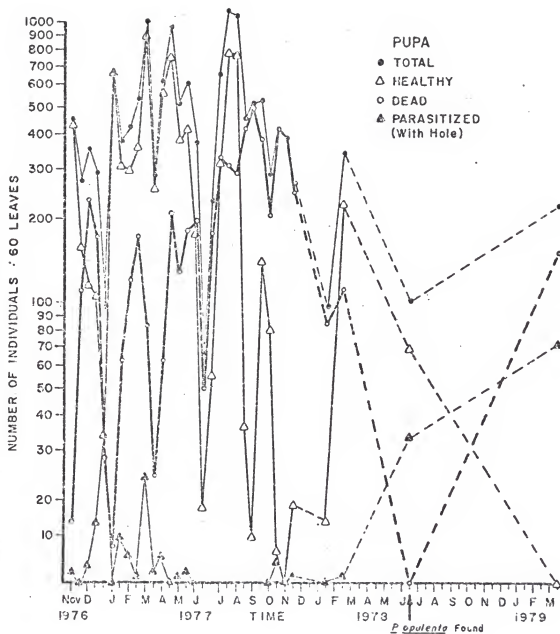


Figure 26. Total, healthy, dead, and parasitized pupa populations of *A. woglumi* observed on leaves of *C. sinensis* var. "Valencia" at Gloria de Lara, Sarare. (For an explanation of dashed line, see page 38.)

Figure 27 and Table 11 show the percentage of parasitism in dissected live forms (nymphs III and pupae) of citrus blackfly per sample.

From the data it is evident that the citrus blackfly was not subject to high levels of unexplained mortality prior to July 1977 and that a significant change occurred in the relation of immature stage mortality and total population numbers following this date. Prior to July 1977, there was no relation between number of dead individuals and total number of the population sampled. Following this date, there was an abrupt shift to a direct relation of number of dead individuals and the total number present resulting in coinciding peaks for the 2 categories (Figs. 23, 24, 25, and 26).

Prospaltella opulenta was detected the first time on June 15, 1978, in Gloria de Lara citrus grove when 11.76% of the citrus blackflies included in the samples were parasitized. Adult parasites were seen on the sampled leaves (Table 11). However, P. opulenta had been collected at Sarare city on May 11, 1978, 44 km. from the nearest release point. During this time, P. opulenta was also collected at Tarabana Experimental Station (U.C.O.L.A.), 4 km. from the nearest release point; Barquisimeto city, 10 km. from the nearest release point; Escuela de Agronomia (U.C.O.L.A.), 23 km. from the nearest release point; and on June 24, 1978, P. opulenta was collected at Agua Blanca (Portugues State), 100 km. from the nearest release point.

On June 15, 1978, all nymphal instar populations declined to 0, and only 68 pupae were found (Tables 8 and 10). On March 27, 1979, only 3 first nymphal instars, 20 second nymphal instars, and 32 third

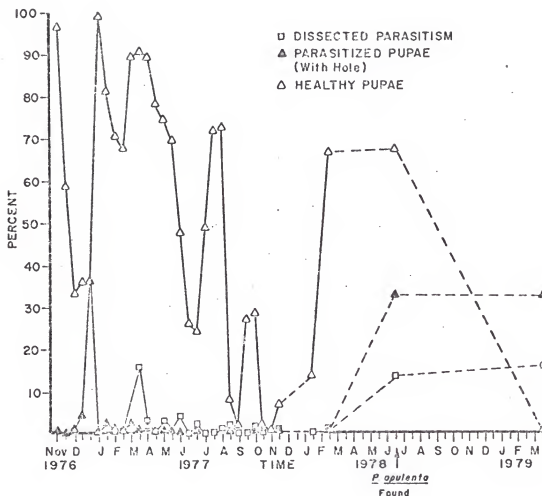


Figure 27. Percent healthy and parasitized (with hole) pupae and percent dissected parasitism of *A. woglumi* observed on leaves of *C. sinensis* var. "Valencia" at Gloria de Lara, Sarare. (For an explanation of dashed line, see page 38.)

TABLE 11
 PERCENT PARASITISM OF DISSECTED LIVE FORMS OF A. WOGLUMI ON 60 LEAVES PER SAMPLE
 LOCALITY: SARARE ("GLORIA DE LARA" CITRUS ORCHARD)

Date	% Infested Leaves ¹	Infestation Index ²	Dissected		Parasitism		% of Parasites		Adults Observed Field	
			N	III Pupa	% Parasitism	% Healthy	Cales sp.	P. opulenta	Cales sp.	P. opulenta
02/11/77	30.33	32.80	3	32	0.00	100.00	0.00	0.00	0	0
02/25/77	46.67	47.60	7	51	0.00	100.00	0.00	0.00	0	0
03/10/77	46.67	66.82	0	100	8.00	92.00	8.00	0.00	0	0
03/24/77	61.67	63.52	6	96	15.69	84.31	15.69	0.00	0	0
04/11/77	48.33	56.90	3	97	3.00	97.00	3.00	0.00	0	0
04/21/77	46.67	41.63	10	90	0.00	100.00	0.00	0.00	0	0
05/05/77	55.00	28.72	0	100	3.00	97.00	3.00	0.00	1	0
05/19/77	53.33	33.03	0	100	1.00	99.00	1.00	0.00	2	0
06/02/77	55.00	68.48	0	100	4.00	96.00	4.00	0.00	0	0
06/16/77	68.33	81.28	5	17	0.00	100.00	0.00	0.00	1	0
06/30/77	65.00	67.37	73	27	2.00	98.00	2.00	0.00	0	0
07/14/77	69.33	62.75	22	78	0.00	100.00	0.00	0.00	0	0
07/28/77	75.00	57.03	8	92	0.00	100.00	0.00	0.00	0	0
08/11/77	95.00	177.43	3	97	1.00	99.00	1.00	0.00	0	0
08/25/77	73.33	77.82	16	36	1.52	98.08	1.52	0.00	0	0
09/08/77	76.67	75.47	94	9	0.00	100.00	0.00	0.00	0	0
09/22/77	58.33	25.82	26	75	0.00	100.00	0.00	0.00	0	0
10/06/77	48.33	17.78	0	78	1.28	98.72	1.28	0.00	0	0

TABLE 11--Continued

Date	% Infested Leaves ¹	Infestation Index ²	Dissected		Parasitism		% of Parasites		Adults Observed Field	
			N	III Pupa	% Parasitism	% Healthy	Cales sp.	P. opulenta	Cales sp.	P. opulenta
10/20/77	48.33	18.27	39	6	0.00	100.00	0.00	0.00	0	0
11/03/77	15.00	5.52	0	0	0.00	0.00	0.00	0.00	0	0
11/17/77	25.00	9.37	82	18	0.00	100.00	0.00	0.00	0	0
01/12/78	23.33	9.73	63	13	0.00	100.00	0.00	0.00	0	0
02/20/78	38.33	15.48	3	98	0.00	100.00	0.00	0.00	0	0
05/15/78	13.33	1.13	0	68	13.24	86.76	1.48	11.76	1	5
03/27/79	13.33	0.97	32	0	15.63	84.38	0.00	15.63	3	1

¹The % of infested leaves does not include leaves where only adults were found.

% Infested Leaves = $\frac{\text{No leaves with live forms}}{60}$

²Infestation Index = $\frac{(\text{Eggs} + \text{NI} + \text{NII} + \text{NIII} + \text{Pupae})}{\text{No of sampled leaves}} = \frac{\text{live forms}}{60}$

nymphal instars were found. Complete biological control had been achieved.

Other natural enemies found as mortality factors were Nodita sp., Phlugis teres, Scymnus sp., Delphastus spp., Azya sp., Zelus sp., the jumping spiders (Attidae), and a Dipteran: Dolichopodidae.

Statistical Analysis

A simple correlation analysis was made in an effort to establish reliability of the less laborious square centimeter population sampling method used by Chavez (1974) for sampling populations of the citrus whitefly, Dialeurodes citri Ashm. The correlation between the total leaf and 1 square centimeter counts gave a high r value for Santa Lucia and Apoliro citrus grove but not for Gloria de Lara citrus grove (Tables 12, 13, and 14). Based on these correlation coefficients, a simple regression analysis including the linear and quadratic models was performed for establishing the prediction equations for Santa Lucia and Apoliro citrus groves (Tables 15 and 16). Coefficients of determinations were low for eggs (28%) and third nymphal instars (37%) at Hacienda Santa Lucia and for second nymphal instars (28%) at Apoliro Experimental Orchard.

Tables 17 and 18 show the regression coefficients, standard error and probability $>|t|$ for each prediction equation.

From the data it is evident that the citrus blackfly population had different behavior for each immature instar at each farm. This could be due to the parasite (P. opulenta) which after its release soon increased sufficiently to have a measurable effect on the host population, first by increasing the dead individuals and second by

TABLE 12

CORRELATION COEFFICIENTS FOR SQUARE CENTIMETER AND
TOTAL LEAF COUNTS FOR EACH VARIABLE STUDIED AT
HACIENDA SANTA LUCIA

Variable	r
EG	.527
N I	.843
N II	.866
N III	.612
Pu	.777

EG: Egg

N(I-II-III): Nymph (first, second, and third instar)

Pu: Pupa

r : Correlation coefficient

TABLE 13
 CORRELATION COEFFICIENTS FOR SQUARE CENTIMETER AND
 TOTAL LEAF COUNTS FOR EACH VARIABLE STUDIED AT
 APOLIRO EXPERIMENTAL ORCHARD

Variable	r
EG	.777
N I	.856
N II	.533
N III	.795
Pu	.757

EG: Egg

N(I-II-III): Nymph (first, second, and third instar)

Pu: Pupa

r : Correlation coefficient

TABLE 14
 CORRELATION COEFFICIENTS FOR SQUARE CENTIMETER AND
 TOTAL LEAF COUNTS FOR EACH VARIABLE STUDIED AT
 GLORIA DE LARA CITRUS ORCHARD

Variable	r
EG	.273
N I	.351
N II	.099
N III	.844
Pu	.171

EG: Egg

N(I-II-III): Nymph (first, second, and third instar)

Pu: Pupa

r : Correlation coefficient

TABLE 15

PREDICTION EQUATION INCLUDING THE LINEAR AND QUADRATIC
EFFECT OF THE COUNT PER SQUARE CENTIMETER
AND R^2 VALUES FOR HACIENDA SANTA LUCIA

	Equation ($\hat{Y} = \hat{b}_0 + \hat{b}_1 X + \hat{b}_2 X^2$)	R^2
1)	EG = 8.7418 + 3.8291 EGS - 0.3589 EGS ²	.2775
2)	N I = 3.2053 + 2.9558 NIS - 0.1933 NIS ²	.7115
3)	N II = 1.0113 + 2.7782 NIIS + 0.1685 NIIS ²	.7503
4)	N III = 0.9561 + 4.3478 NIIIS - 0.4869 NIIIS ²	.3749
5)	PU = 0.8775 + 3.4497 PUS - 0.1891 PUS ²	.6040

EG: Egg population

EGS: Egg population within a square centimeter

EGS²: Square of egg population within a square centimeter

N(I-II-III): Nymphal (first, second, third instars) population

N(I-II-III)S: Nymphal (first, second, third instars) population
within a square centimeter

N(I-II-III)S²: Square of nymphal (first, second, third instars)
population within a square centimeter

PU: Pupal population

PUS: Pupal population within a square centimeter

PUS²: Square of pupal population within a square centimeter

R^2 : Coefficient of determination (% variation in Y variable
accounted for by changes in X variable)

TABLE 16

PREDICTION EQUATION INCLUDING THE LINEAR AND QUADRATIC
EFFECT OF THE COUNT PER SQUARE CENTIMETER AND
 R^2 VALUES FOR APOLIRO EXPERIMENTAL ORCHARD

	Equation ($\hat{Y} = \hat{b}_0 + \hat{b}_1 X + \hat{b}_2 X^2$)	R^2
1)	EG = 15.9411 + 3.1797 EGS - 0.7190 EGS ²	.6036
2)	N I = 6.0445 + 3.1358 NIS - 0.2009 NIS ²	.7329
3)	N II = 1.6262 + 3.4778 NIIS - 0.8437 NIIS ²	.2839
4)	N III = 1.6025 + 3.2595 NIIIS - 0.4557 NIIIS ²	.6312
5)	PU = 2.7371 + 2.9995 PUS + 0.8886 PUS ²	.7574

EG: Egg population

EGS: Egg population within a square centimeter

EGS²: Square of egg population within a square centimeter

N(I-II-III): Nymphal (first, second, third instars) population

N(I-II-III)S: Nymphal (first, second, third instars) population within a square centimeter

N(I-II-III)S²: Square of nymphal (first, second, third instars) population within a square centimeter

PU: Pupal population

PUS: Pupal population within a square centimeter

PUS²: Square of pupal population within a square centimeter

R^2 : Coefficient of determination (% variation in Y variable accounted for by changes in X variable)

TABLE 17

REGRESSION COEFFICIENTS, STANDARD ERROR AND PROBABILITY
 $>|t|$ FOR EGGS, NYMPHAL (FIRST, SECOND, AND THIRD
 INSTAR) AND PUPAE FOR HACIENDA SANTA LUCIA

	$\hat{b}_1$	$\hat{b}_2$
EG	3.8291	-0.3589
SE	± 0.1670	± 0.0003
$P > t $	0.001	0.001
N I	2.9558	-0.1933
SE	± 0.0834	± 0.0007
$P > t $	0.001	0.001
N II	2.7782	0.1685
SE	± 0.0773	± 0.0013
$P > t $	0.001	0.100
N III	4.3478	-0.4869
SE	± 0.1908	± 0.0052
$P > t $	0.001	0.001
PU	3.4497	-0.1891
SE	± 0.1050	± 0.0019
$P > t $	0.001	0.001

TABLE 18

REGRESSION COEFFICIENTS, STANDARD ERROR AND PROBABILITY $>|t|$
 FOR EGGS, NYMPHAL (FIRST, SECOND, AND THIRD INSTAR) AND
 PUPAE FOR APOLIRO EXPERIMENTAL ORCHARD

	$\hat{b}_1$	$\hat{b}_2$
EG	3.1797	-0.7190
SE	± 0.0962	± 0.0003
$P > t $	0.001	0.001
N I	3.1358	-0.2009
SE	± 0.0623	± 0.0002
$P > t $	0.001	0.001
N II	3.4778	-0.8437
SE	± 0.0549	± 0.0002
$P > t $	0.001	0.001
N III	3.2595	-0.4557
SE	± 0.0990	± 0.0014
$P > t $	0.001	0.001
PU	2.9995	0.8886
SE	± 0.1493	± 0.0021
$P > t $	0.001	0.001

eliminating citrus blackfly from the leaves. This effect was reflected by the correlation coefficients which had lower values than those found by Chavez in 1974 in populations of whitefly which started to increase after the winter season and were not under any high level of stress by any mortality factor.

At Gloria de Lara citrus grove it is evident that the effect of fungus diseases which tended to be concentrated in the area where the square centimeter was placed and the later biological control of the citrus blackfly population were responsible for low value of the correlation coefficients found at this farm.

Discussion

There were 5 generations of Aleurocanthus woglumi at each of the citrus groves studied during the year November 1976-November 1977. The time of adult emergence of the generations was different in each grove and depended on the climatic condition as well as the management of the grove. Even the seemingly minor difference between climatic conditions of the Santa Lucia and Apoliro citrus groves had a pronounced effect on the citrus blackfly populations. The first generation at Santa Lucia citrus grove was nearly a month later than at the Apoliro grove. It is, therefore, not surprising to find in the literature variations in details of life history from different authors.

The only mortality factor that reduced the A. woglumi populations and kept them at a continuing low level was the introduced parasite, Prospaltella opulenta. However, Cales sp. was the only native parasite of citrus blackfly found in the Central-Western region of Venezuela. Cales sp. is a parasite of wooly whitefly (Aleurothrixus floccosus

(Maskell)) and parasitizes citrus blackfly as an alternate host. However, this native parasite plays an important factor in the establishment and colonization of P. opulenta as it served as a host for development of male P. opulenta. Males of P. opulenta develop as secondary endoparasites of conspecific female pupae or pupae of closely allied species, in this case Cales sp. Thus, the female larvae of P. opulenta are primary parasites of immature stages of citrus blackfly while the male larvae are hyperparasites. With Cales sp. present fewer P. opulenta were hyperparasitized for production of males, and the population could increase more rapidly. Once P. opulenta became well established, the number of citrus blackfly nymphs and pupae dead of all causes peaked at times coinciding with the peaks of total numbers of all categories of the citrus blackfly and became synchronized with each generation of the citrus blackfly. This was clearly due to presence of P. opulenta as a new mortality factor. Dead individuals of citrus blackfly increased as an effect of parasite host feeding as well as by stinging activity of the female parasites that resulted in death of hosts in which no egg was laid or, if laid, did not develop. When P. opulenta increased sufficiently to have a measurable effect on the host population, Cales sp. was completely displaced as a parasite of citrus blackfly. Populations of A. woglumi disappeared in sample collections indicating that complete biological control was achieved 18 months after the release of P. opulenta. However, it may eventually be necessary to introduce one or more additional species of parasites in order to avoid the resurgences of citrus blackfly as occurred in Jamaica and on a more recent basis in Mexico.

Other mortality factors were identified in the field as well as in the leaf samples collected for count of the immature stages. The factors responsible for mortality were the fungi, Aschersonia aleyrodis, A. goldiana, and Aegerita webberi; the coccinellids, Delphastus pusillus, Delphastus sp. near argentinicus, Delphastus sp., Azya sp., and Cycloneda sanguinea; an anthocorid predator (Hemiptera: Anthocoridae); the assassin bug, Zelus sp.; the neuropteran, Nodita sp., and Mantispidia sp. near viridis; the tettigoniid predator, Phlugis teres; a dipteran predator (Dolichopodidae); the jumping spiders (Attidae); and few abiotic factors such as heavy rainfall, insecticide and unexplained mortality. However, the combined effect of these observed and suspected mortality factors did not prevent the increase of citrus blackfly populations when more favorable conditions returned prior to release of P. opulenta.

The number of plant species used for oviposition by citrus blackfly varies directly with the size of the adult population; however, the survival of the immature A. woglumi is not equal on all plants. Only a few plant species are capable of supporting complete development of citrus blackfly from eggs to adults. These are true "host plants" that may act as potential dispersal agents. However, experimental evidence has shown that populations of the citrus blackfly cannot persist on these hosts in the absence of nearby citrus (Dowell et al., 1980). While the potential role of the marginal or nonpreferred hosts as a factor in population dynamics of the citrus blackfly is now well understood, little is known about the role that the citrus blackfly population on these host plants plays in the population dynamics of P. opulenta. In view of the high searching and dispersal capabilities of P. opulenta, there seems no reason why it should not find and parasitize citrus

blackfly on noncitrus plants. However, there remains the possibility that P. opulenta may exhibit a habitat preference that would restrict its searching activity to citrus. To date, this has not been demonstrated.

Statistical analysis of square centimeter versus total leaf count data indicated that prediction equations based on square centimeter count could serve as a reliable basis for estimating normal unstressed populations of immature A. woglumi; however, if the populations are subjected to more or less constant stress and fail to return to high population levels, the correlation coefficients were too low to allow construction of reliable prediction equations.

Perhaps the single most important conclusion to be derived from the studies in Venezuela and the review of the extensive literature on citrus blackfly is that it need not be a pest. When introduced into a new area, it has repeatedly demonstrated its ability to be a devastating pest of citrus. At the same time, the recent experience in Venezuela supported by results of parasite introductions into most of the countries now infested by citrus blackfly show that it can be quickly brought under highly effective control through introduction of parasites, with Prospaltella opulenta, P. clypealis, and Amitus hesperidum being the most useful. This appears to be true regardless of the climatic conditions and cultural practices of the area in which citrus is grown. Only in situations where the trees are subject to frequent and sustained exposure to insecticides (as in a grove surrounded by cotton) will parasites fail to provide adequate control. Finally, control of the pest in all countries, where parasites have been introduced, has been achieved at an almost absurdly small cost.

LITERATURE CITED

- Abbas, H. M., M. S. Kahn, and H. Haque. 1955. Blackfly of citrus (Aleurocanthus woglumi Ashby) in Sind and its control. Agr. Pakistan, 6:5-23; Abstract in Rev. Appl. Entomol. 46:72, 1958.
- Alam, M. Z., A. Ahmed, S. Alam, and M. A. Islam. 1965. A review of research. Division of Entomology (1947-64). Agr. Inf. Serv. and Pakistan Agr. Res. Inst. Dacca. 272p. Abstract in Rev. Appl. Entomol. 55:1556, 1967.
- Angeles, N. de J., J. R. Dedory, N. B. de Martinez, P. O. Paredes, and J. R. Requena. 1972. Aportes en el estudio de hospederas de la "mosca prieta de los citricos," Aleurocanthus woglumi Ashby, en Venezuela. Agro. Trop. 22(5):549-53.
- Angeles, N. de J., J. R. Dedordy, P. O. Paredes, and J. R. Requena. 1971. Mosca prieta (Aleurocanthus woglumi Ashby) de los citricos en Venezuela. Agro. Trop. 21(2):71-5.
- Angeles, N. de J., R. G. Oakley, y J. A. Osorio. 1968. Presencia en Venezuela de Aleurocanthus woglumi Ashby (Aleyrodidae-Homoptera) mosca prieta de los citricos. Agron. Trop. 18(4):487-8.
- Angeles, N. de J., J. A. Osorio, and R. G. Oakley. 1967. First record of citrus blackfly. F.A.O. Plant Prot. Bull. 15(6):117.
- Angeles, N. de J., P. O. Paredes, N. B. de Martinez, J. R. Dedordy, J. R. Requena, y M. de Bornas. 1974. Registro de nuevas localidades, en la distribucion de la "mosca prieta de los citricos" Aleurocanthus woglumi Ashby, en Venezuela. Agro. Trop. 24(2):107-11.
- Anonimo. 1917. La mosca prieta y medios para combatrila. Secretaria de Agricultura, Comercio y Trabajo. Comision de Sanidad Vegetal. Cuba. Circular No. 1.
- Anonimo. 1952. Lista de plantas hospederas de la mosca prieta (Aleurocanthus woglumi). Fitofilo, 6(4):26-9.
- Anonimo. 1964. Concentracion de datos de los trabajos desarrollados contra la mosca prieta de los citricos durante los anos de 1959 a 1964. Fitofilo, 18(43):46-8.
- Anonymous. 1959. Pests and diseases number. Plant Prot. Bull. Delhi 11:1-70; Abstract in Rev. Appl. Entomol. 53:306, 1965.

- Anonymous. 1968. Plant quarantine announcements. F.A.O. Plant Prot. Bull. 16:116-7.
- Anonymous. 1976a. Citrus blackfly returns. Plant Ind. News. 17(3):3-5.
- Anonymous. 1976b. Citrus blackfly moves into Palm Beach County. Plant Ind. News. 17(4):25.
- Ashby, S. F. 1915. Note on diseases of cultivated crops observed in 1913-4. Dep. Agr. Jamaica Bull. 2(8):321-2.
- Baker, A. C., and A. Dempf. 1937. Notes on some Mexican Aleyrodidae. (Sobretiro) (Mex.) Univ. Nac., Inst. Biol. An. 8(4):611.
- Bedford, E. C. G., E. D. Thomas. 1965. Biological control of the citrus blackfly, Aleurocanthus woglumi (Ashby) (Homoptera: Aleyrodidae) in South Africa. J. Entomol. Soc. S. Africa. 28:117-32.
- Bennett, F. D. 1966. Current status of citrus blackfly and introduced parasites in Barbados. J. Agr. Soc. Trinidad and Tobago, 66:7-8.
- Bennett, F. D. 1971. Some recent successes in the field of biological control in the West Indies. I Cong. Latino-americano de Entomol. Cusco, Peru. Soc. Entomol. del Peru. 55:40.
- Bennett, F. D., and L. W. van Whervin. 1965. The occurrence of Aleurocanthus woglumi Ashby in Barbados and the establishment of its natural enemies. F.A.O. Plant Prot. Bull. 13(4):2-4.
- Bennett, F. D., and L. W. van Whervin. 1966. Occurrence of the citrus blackfly in Barbados. J. Agr. Soc. Trinidad and Tobago. 66:3-6.
- Berry, P. A., y J. M. McGough. 1932. La mosca prieta de los citrus y su desarrollo en Cuba. Secretaría de Agricultura, Comercio y trabajo. Seccion de Sanidad Vegetal. Cuba.
- Bosman, T. 1959. Blackfly can destroy entire crop. Farm. S. Africa, 35(6):6,7,9,10,27.
- Brown, A. C. 1937. Report of the grove Inspection Department. In Report for the Period July 1, 1934-June 30, 1936. Sta. Plant Board, Florida. 21-6.
- Brown, A. C. 1939. Report of the grove Inspection Department. In Report for the period July 1, 1936-June 30, 1938. Sta. Plant Board, Florida. 15-7.
- Browne, F. G. 1968. Pests and diseases of forest plantation trees. Clarendon Press, Oxford.

- Bruner, S. C. 1931. Informe del Departamento de Entomologia y Fitopatologia. Ejercicio de 1929 a 1930. Secretaria de Agricultura, Comercio y Trabajo. Est. Exp. Agr. Santiago de las Vegas. Cuba. 74p.
- Bruner, S. C. 1954. Sobre la mosca prieta de las plantas citricas en Cuba, y su control. Rev. Agr. (Cuba) 37(2):51-9.
- Bruner, S. C., y L. Boucle. 1945. La mosca prieta en Cuba y su control. Rev. del Ministerio de Agricultura, 4(1):50-3.
- Bruner, S. C., L. C. Scaramuzza, y A. R. Otero. 1945. Catalogo de los insectos que atacan a las plantas economicas de Cuba. Est. Exp. Agro. Santiago de las Vegas. Cuba. 246p.
- Bustillo, P. A. E. 1970. La mosca negra de los citricos, Aleurocanthus woglumi (Ashby), un problema severo en el Tolima. Agr. Trop. 26:721-2; Abstract in Rev. Appl. Entomol. 61(7): 2379, 1973.
- Carrillo, T. R., J. M. Ramirez, and R. C. Zappe. 1966. Erradicacion de la mosca prieta de los citricos en la zona de control quimico en el noreste de Mexico. Fitofilo, 19(52):33-41.
- Cavin, G. 1976. Public forum on the citrus blackfly in Florida. Lakeland, Florida. February 19.
- Chapot, H. 1975. The citrus plant. In E. Häfliger (ed). Citrus, Ciba-Geigy Agrochemicals. Ciba-Geigy Ltd. Tech. Mono. 4:6-13
- Chavez, H. A. 1974. Early season population of whiteflies on citrus and ornamentals in North Central Florida. M.S. Thesis, University of Florida. 39p.
- Cherry, R., R. V. Dowell, and G. Fitzpatrick. 1978. Survival of immature citrus blackfly, Aleurocanthus woglumi, and its parasite, Amitus hesperidum, on excised leaves. Envir. Entomol. 7(1):28-30.
- Clausen, C. P. 1936. Insect parasitism and biological control. Ann. Entomol. Soc. Ame. 24:201-23.
- Clausen, C. P. 1978. Introduced parasites and predators of arthropod pests and weeds: A world review. U.S.D.A.-A.R.S. Agr. Handbook, 480:27-35.
- Clausen, C. P., and P. A. Berry. 1932. The citrus blackfly in Asia, and the importation of its natural enemies into tropical America. U.S.D.A. Tech. Bull. 320:1-58.
- Comstock, J. H. 1967. An Introduction to Entomology. 9th Ed. Rev. Comstock Publ. Assoc., Ithaca, New York.

- Corbett, G. H. 1935a. Three new Aleurodids (Hem.). *Stylops*, 4:8-10.
- Corbett, G. H. 1935b. Malayan Aleurodidae. *J.F.M.S. Museum*, 17:722-853.
- Dietz, H. F., and J. Zetek. 1920. The blackfly of citrus and other subtropical plants. *U.S.D.A. Bull.* 885:1-57.
- Dowell, R. V. 1979a. Host selection by the citrus blackfly *Aleurocanthus woglumi* (Homoptera: Aleyrodidae). *Ent. Exp. and Appl.* 25:289-96.
- Dowell, R. V. 1979b. Synchrony and impact of *Amitus hesperidum* (Hym.: Platygasteridae) on its host, *Aleurocanthus woglumi* (Hym.: Aleyrodidae) in Southern Florida. *Entomophaga*, 24(3):221-27.
- Dowell, R. V., R. H. Cherry, G. E. Fitzpatrick, J. A. Reinert, and J. L. Knapp. 1980. Biology, plant-insect relations and control of the citrus blackfly, *Aleurocanthus woglumi* Ashby (Homoptera: Aleyrodidae). *I.F.A.S. Tec. Bull.* (in press).
- Dowell, R. V., and G. E. Fitzpatrick. 1978. Effects of temperature on the growth and survivorship of the citrus blackfly (Homoptera: Aleyrodidae). *Can. Entomol.* 110:1347-50.
- Dowell, R. V., G. E. Fitzpatrick, and J. A. Reinert. 1979. Biological control of citrus blackfly in Southern Florida. *Environ. Entomol.* 8(4):595-7.
- Dowell, R. V., J. A. Reinert, and G. E. Fitzpatrick. 1978. Development and survivorship of the citrus blackfly, *Aleurocanthus woglumi* on six citrus host. *Environ. Entomol.* 7:524-5.
- Dowell, R. V., and B. Steinberg. 1979. Development and survival of immature citrus blackfly (Homoptera: Aleyrodidae) on twenty-three plant species. *Ann. Entomol. Soc. Amer.* 72:721-4.
- Dozier, H. L. 1932. Introduction of *Eretmocerus serius* Silv. into Haiti. *J. Econ. Entomol.* 25:414.
- Dozier, H. L. 1933. Miscellaneous notes and descriptions of Chalcidoid parasites (Hymenoptera). *Proc. Entomol. Soc. Wash.* 35(6):85-100.
- Ebeling, W. 1950. Subtropical entomology. Lithotype Process Co., San Francisco, Calif. 505-8.
- Ebeling, W. 1959. Subtropical fruit pest. Div. Agr. Sci., Univ. Calif., Berkeley, California.

- Edwards, W. H. 1932. Control of citrus blackfly. The introduction in Jamaica of a natural enemy (Eretmocerus serius Silv.) of the citrus blackfly (Aleurocanthus woglumi Ash.). J. Jamaica Agric. Soc. 36(6):280. Abstract in Rev. Appl. Entomol. 20:512, 1932.
- Enkerlin, S. D. 1976. Some aspects of the citrus blackfly (Aleurocanthus woglumi Ashby) in Mexico. Proc. Tall Timbers Conf. 6:65-76.
- Flanders, S. E. 1969. Herbert D. Smith's observation on citrus blackfly parasites in India and Mexico and the correlated circumstances. Can. Entomol. 101:467-80.
- Fomento Agropecuario. 1980. Estadísticas Agrícolas: MAC y BCV. Banco de Venezuela S.A. 5(45):1-9.
- Gentry, J. W. 1965. Crop insects of Northeast Africa-Southeast Asia. Agr. Handbook. U.S.D.A. 273:1-210.
- Geraud P., F. 1979. Control biológico de la mosca prieta de los cítricos Aleurocanthus woglumi Ashby, Homoptera: Aleyrodidae, mediante la introducción y establecimiento de insectos parásitos específicos. Informe de Actividades del Periodo Agosto 1974-Febrero 1979. FUSAGRI. Est. Exp. de Cagua, Edo. Aragua, Venezuela.
- Geraud P., F., G. Perez, N. B. de Martinez, y J. Teran. 1977. La mosca prieta de los cítricos en Venezuela y su control biológico. V Reun. Nac. Cont. Biol. y Sect. Agrope. Org. Tamaulipas, Mexico.
- Hart, W. G., H. W. Gausman, and R. R. Rodriguez. 1976. Citrus blackfly (Hemiptera: Aleyrodidae), feeding injury and its influence on the spectral properties of citrus foliage. J. of the Rio Grande Valley Hort. Soc. 30:37-43.
- Hart, W. G., S. J. Ingle, M. R. Davis, and C. Mangum. 1973. Aerial photography with infrared color film as a method of survey for citrus blackfly. J. Econ. Entomol. 66:190-4.
- Hart, W. G., A. Selhime, D. P. Harlan, S. J. Ingle, R. M. Sanchez, R. H. Rhode, C. A. Garcia, J. Caballero, and R. L. Garcia. 1978. The introduction and establishment of parasites of citrus blackfly, Aleurocanthus woglumi in Florida (Hem.: Aleyrodidae). Entomophaga, 23(4):361-6.
- Hill, D. 1975. Agricultural insect pests of the tropics and their control. Cambridge University Press, Cambridge, London.
- Howard, F. W. 1979. Comparación de seis especies de Citrus como plantas hospederas de Aleurocanthus woglumi Ashby. Folia Entomol. Mexicana, 41:33-40.

- Howard, F. W., and P. L. Neel. 1977. Host plant preferences of citrus blackfly, Aleurocanthus woglumi Ashby (Homoptera: Aleyrodidae), in Florida. Proc. Int. Soc. Citriculture, 2:489-92.
- Husain, A. M., and A. W. Kahn. 1945. The citrus Aleyrodidae (Homoptera) in the Punjab and their control. Mem. Entomol. Soc. Indian, 1:1-41.
- Hutson, J. C. 1917. The spiny citrus whitefly. A potential pest of citrus trees. Agr. News West Indies, 16(384):10-1.
- Islas, F. 1951. Estudios sobre la biología y combate de la mosca prieta Aleurocanthus woglumi Ashby. Insecta-Homoptera-Aleyrodidae. Fitofilo, 5(2):26-44.
- Jimenez, E. 1963. Control biológico de la mosca prieta en Mexico. Fitofilo, 16(37):6-41.
- Jimenez, E. 1968. La campana contra la mosca prieta de los citricos. Fitofilo, 21(60):23-8.
- Jimenez, E. 1970. Importancia economica del combate biológico de la mosca prieta de los citricos en Mexico. Fitofilo, 23(65):9-11.
- Jimenez, E. 1971. Comportamiento de los enemigos naturales de la mosca prieta de los citricos en la republica Mexicana. Fitofilo, 24(66):2-6.
- Kesterson, J. W., and R. J. Braddock. 1975. Citrus fruit processing. In E. Häfliger (ed). Citrus, Ciba-Geigy Agrochemicals. Ciba-Geigy Ltd. Tech. Mono. 4:75-80.
- Ketner, C. F., and J. G. Rosier. 1978. Citrus blackfly controlled biologically. Texas Agr. Prog. 2:19-20.
- Kiriukhin, G. 1947. Quelques Aleurodidae de L'Iran. Ent. et Phytopath. Appl. Teheran, 5:22-8. In Russell, L. M. 1962. The citrus blackfly. F.A.O. Plant Prot. Bull. 10(2):36-8.
- Knorr, L. C., E. C. Paterson, and J. H. Proctor. 1961. World citrus problems. F.A.O. Plant Prot. Bull. 9(6):97.
- Martínez, N. de. 1978. Enemigos naturales de la mosca prieta de los citricos (Aleurocanthus woglumi Ashby) en Venezuela. III Enc. Venezolano de Entomología, Maracaibo, Venezuela.
- Martínez, N. B. de, y N. de J. Angeles. 1973. Contribucion al conocimiento de la biología de la "Mosca Prieta de los Citricos" Aleurocanthus woglumi Ashby, en Venezuela. Agro. Trop. 23(4):401-406.

- Mateos, D. L. A. 1963. Control biológico de la mosca prieta en Mexico. *Fitofilo*, 16(37):5-41.
- McGuire, J. U., and B. S. Crandall. 1967. Survey of insect pests and plant diseases of selected food crops of Mexico, Central America and Panama. U.S.D.A.-A.I.D. 157p.
- Morrill, A. W. 1903. Notes on some Aleyrodes from Massachusetts, with descriptions of new species. *Psyche*, 80-5.
- Morrill, A. W., and E. A. Back. 1911. White flies injurious to citrus in Florida. U.S.D.A. Bur. Entomol. Bull. 92:1-109.
- Morrill, A. W., and E. A. Back. 1912. Natural control of white flies in Florida. U.S.D.A. Bur. Entomol. Bull. 102:1-78.
- Müller, H. J. 1956. Aleyrodina (Aleurodina) C. Börner, in Soraure Handbuch der Pflanzenkrankheiten, 5(3):331-50. In Russell, L. M. 1962. The citrus blackfly. F.A.O. Plant Prot. Bull. 10(2):36-8.
- Newell, W. 1918. The "Blackfly," a serious menace to citrus. Calif. Citrograph. 3(9):209, 216-7.
- Newell, W., and A. C. Brown. 1939. Eradication of the citrus blackfly in Key West, Fla. J. Econ. Entomol. 32(5):680-2.
- Nie, N. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent. 1975. Statistical Package for the Social Sciences (SPSS). McGraw-Hill, New York. 675p.
- Osorio, J. M. 1946. La mosca prieta, insecto reliquia (Cuba). Control de Plagas, 3:31.
- Osorio, J. M. 1970. La mosca prieta de los citricos, terrible amenaza para estos frutales y otros en Venezuela. Aquí la Universidad. U.C.O. 3-5.
- Osorio, J. M., H. A. Chavez, F. Ferrer, y J. Morales. 1972. Observaciones sobre la mosca prieta de los citricos en Venezuela, su distribucion actual y enemigos naturales nativos (Aleyrodidae: Aleurocanthus woglumi Ashby). VIII Jornadas Agronomicas. Aragua, Venezuela. 25p.
- Posada, L., y F. Garcia. 1976. Lista de predadores, parasitos y patogenos de insectos registrados en Colombia. Bol. Tec. 41:1-90.
- Pratt, R. M. 1958. Florida guide to citrus insects, diseases and nutritional disorders in color. Fla. Agr. Exp. Sta. 191p.

- Pschorn-Walcher, H., and F. D. Bennett. 1967. The successful biological control of the citrus blackfly (Aleurocanthus woglumi (Ashby)) in Barbados, West Indies. PANS (A) 13(4):375-84. Abstract in Rev. Appl. Entomol. 56:77-8, 1968.
- Quaintance, A. L., and A. C. Baker. 1913. Classification of the Aleyrodidae. U.S.D.A. Bur. Entomol. Bull. Tech. Ser. 27, Pt. 1:1-93.
- Quaintance, A. L., and A. C. Baker. 1914. Classification of the Aleyrodidae. U.S.D.A. Bur. Entomol. Bull. Tech. Ser. 27, Pt. 2:94-109.
- Quaintance, A. L., and A. C. Baker. 1916. Aleyrodidae, or white flies attacking the orange, with descriptions of three new species of economical importance. J. Agr. Res. 6(12):459-72.
- Quezada, J. R. 1974. Biological control of Aleurocanthus woglumi (Homoptera: Aleyrodidae) in El Salvador. Entomophaga, 19(3):243-54.
- Richardson, H. H. 1948. Present status of the citrus blackfly and its parasite Eretmocerus serius at Nassau, Bahamas. J. Econ. Entomol. 41(6):980.
- Russell, L. M. 1962. The citrus blackfly. F.A.O. Plant Prot. Bull. 10(2):36-8.
- Sailer, R. I. 1976a. Report on travel in Mexico during the period Oct. 13-Oct. 21. Entomol. and Nematol. Dpt. U. of F. I.F.A.S. Memorandum.
- Sailer, R. I. 1976b. Report on travel to the Republic of Haiti and the Commonwealth of Jamaica during the period Oct. 3-Oct. 10. Entomol. and Nematol. Dpt. U. of F. I.F.A.S. Memorandum.
- Sanchez Riviello, M., R. H. Rhode, W. G. Hart, and P. D. Lara. 1977. Citrus blackflies: Greenhouse culture on hydroponic citrus plants. J. Econ. Entomol. 70(6):808-10.
- Shaw, J. G. 1950a. Hosts of the citrus blackfly in Mexico. U.S.D.A Bur. Entomol. Plant Quar. E. 798:1-16.
- Shaw, J. G. 1950b. Eretmocerus serius as a parasite of the citrus blackfly in Mexico. J. Econ. Entomol. 43:380-2.
- Silvestri, F. 1926. Descrizione de tre specie de Prospaltella e di una di Encarsia (Hymenoptera: Chalcididae) parassiti di Aleurocanthus (Aleyrodidae). E.O.S. 2(2-3):179-89.
- Silvestri, F. 1927. Contribuzione alla conoscenza degli Aleurodidae (Insecta: Hemiptera) viventi su Citrus in Extremo Oriente e dei loro parassiti. Boll. Lab. Zool. Portici. 21:1-60.
- Simmonds, F. J. 1975. Report of work carried out during 1975. Comm. Inst. Biol. Cont. 74p.

- Smith, H. D. 1945. La "Mosca Prieta" de los citricos en la Costa Occidental de Mexico y la importacion y colonizacion de Eretmocerus serius Silv. para su control. Fitofilo, 4(2): 67-103. Abstract in Rev. Appl. Entomol. 35:77-8, 1947.
- Smith, H. D. 1958. Las interrelaciones de los enemigos naturales de la mosca prieta de los citricos en Mexico. Mem. Congr. Nac. I. Ent. Fitop. 300-4.
- Smith, H. D., H. L. Maltby, and E. Jimenez. 1964. Biological control of the citrus blackfly in Mexico. U.S.D.A. Tech. Bull. 1311:1-30.
- Steinberg, B., R. V. Dowell, G. E. Fitzpatrick, and F. W. Howard. 1978. Suitability among native or naturalized plant species of Southern Florida for citrus blackfly development. Fla. Sci. 41(1):57-61.
- Takahashi, R. 1942. Aleurocanthus of Thailand and French Indo-China (Homoptera: Aleyrodidae). Kontyu, 16:57-61.
- van Whervin, L. W. 1968. The introduction of Prospaltella opulenta Silvestri into Jamaica and its competitive displacement of Eretmocerus serius Silvestri. P.A.N.S. 14(4):456-64.
- Watts, W. S., and M. Alam. 1973. Spray trials against the citrus blackfly (Aleurocanthus woglumi) on limes in the Oman. Miscellaneous Report, Overseas Develop. Adm., For. and Comm. Office, 8:7. Abstract in Rev. Appl. Entomol. 62:989, 1974.
- Weems, H. W. 1962. Citrus blackfly, Aleurocanthus woglumi Ashby (Homoptera: Aleyrodidae). Fla. Dep. Agr., Div. Plant Ind. Circ. 9:1-2.
- Wheatley, P. E. 1964. The successful establishment of Eretmocerus serius Silv. (Hymenoptera: Eulophidae) in Kenya. E. Afr. Agr. For. J. 29:236.
- Wolcott, G. N. 1933. An Economic Entomology of the West Indies. Ent. Soc. of Puerto Rico. 450p.
- Wu, F. C. 1935. Catalogus insectorum Sinensium. Fan Mem. Inst. Bio. Peiping. China. 2:127-30.
- Yust, H. R., y M. A. Cevallos. 1954-55. Lista preliminar de plagas de la agricultura del Ecuador. Rev. Ecuat. Ent. Par. 2(3-4): 425-42.
- Zetek, J. 1919. Notes on some insect pests of Costa Rica. J. Econ. Entomol. 12:269.

BIOGRAPHICAL SKETCH

Hugo A. Chavez T. was born on November 23, 1945, in Mene Grande, Zulia State, Venezuela. He attended elementary school in Barquisimeto and graduated from Liceo Lisandro Alvarado in 1963. He entered Universidad Centro Occidental Lisandro Alvarado (UCOLA) and graduated with an Ingeniero Agronomo degree in June, 1969.

He has been employed as a Professor of Entomology in the UCOLA since August, 1969, and at present is also Aggregate Professor, Chief of the Department of Entomology and Zoology, as well as a member of the Postgraduate Commission in the Escuela de Agronomia. He was awarded a fellowship for postgraduate study in the University of Florida, U.S.A., in 1973, and received his M.S. degree in entomology in December, 1974. Mr. Chavez has published 4 technical papers and has presented papers at various entomological meetings. He was president of the II Encuentro Venezolano de Entomologia in 1977. He is a member of the Colegio de Ingenieros de Venezuela, Sociedad Venezolana de Ingenieros Agronomos, Asociacion de Profesores de la UCOLA, Sociedad Venezolana de Entomologia, Asociacion Latinoamericana de Ciencias Agricolas, Entomological Society of America, Florida Entomological Society, International Organization for Biological Control of Noxious Animals and Plants, and IPM Practitioner.

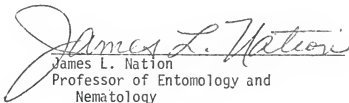
He is married to Maria Ines Ugarte and has a son, Luis Alejandro, and 2 daughters, Maria Sofia and Monica Maria.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



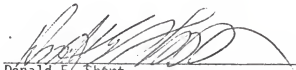
Reece I. Sailer, Chairman
Graduate Research Professor of
Entomology and Nematology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



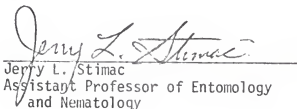
James L. Nation
Professor of Entomology and
Nematology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



Donald E. Short
Associate Professor of Entomology and
Nematology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



Jerry L. Stimac
Assistant Professor of Entomology
and Nematology

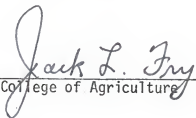
I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



Francis W. Zettler
Professor of Plant Pathology

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June 1980



Dean, College of Agriculture

Dean, Graduate School